A CORRELATION OF THE ENGINEERING CHARACTERISTICS OF ORGANIC SOILS IN NEW YORK STATE

(PRELIMINARY)

BY
L. H. MOORE
ASSOCIATE SOILS ENGINEER

BUREAU OF SOIL MECHANICS
JANUARY 1962

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PRELIMINARY

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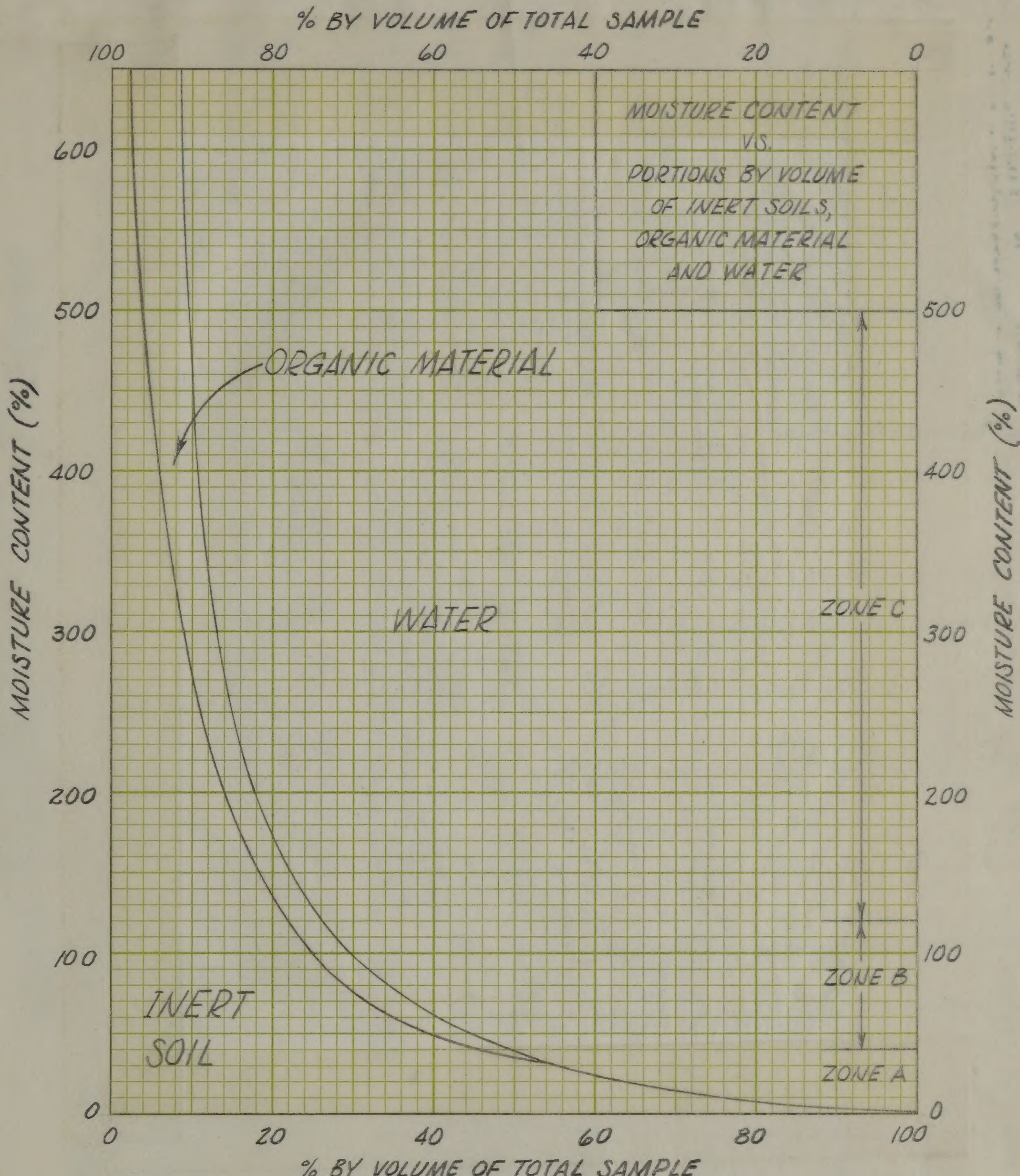
BUREAU OF SOIL MECHANICS
NEW YORK STATE DEPARTMENT OF PUBLIC WORKS

JANUARY 1962



Example showing use of chart:

At Moisture Content of 200% a saturated soil contains by volume 14% inert soil, 4% organic material and 82% water.

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STATE OF NEW YORK **DEPARTMENT OF PUBLIC WORKS** DIVISION OF CONSTRUCTION BUREAU OF SOIL MECHANICS	
FIGURE 1 CORRELATION OF ENGINEERING CHARACTERISTICS OF ORGANIC SOILS	
APPROVED 19	DISTRICT NO. COUNTY
PRINCIPAL SOILS ENGINEER	DWG. NO SM/1606A

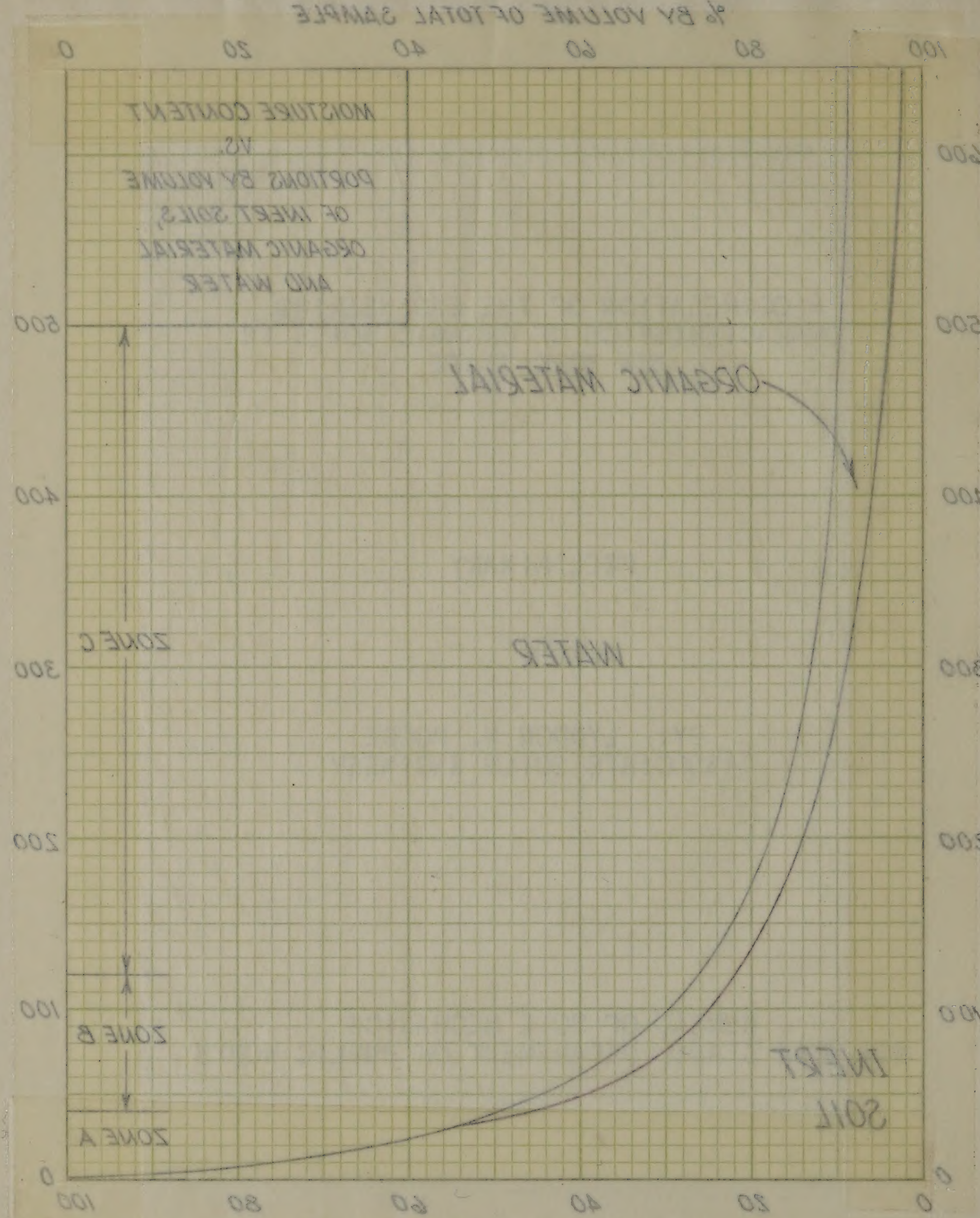

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FIGURE 1
CORRELATION OF ENGINEERING CHARACTERISTICS OF ORGANIC SOILS

APPROVED	19	DISTRICT NO. COUNTY
PRINCIPAL SOILS ENGINEER		DWG. NO. SM1606A

PRELIMINARY CHART FOR ESTIMATING
SHEARING STRENGTHS OF SWAMP SOILS
BASED ON SOIL IDENTIFICATION AND MOISTURE CONTENT

TYPES OF SHEARING STRENGTH INDICATED

1.) Average in-place shearing strength (S_s) expressed in lbs. per sq. ft. for case of rapid fill construction.

2.) Consolidated-Undrained strength, (ϕ and C) for estimating strength increase with consolidation.

ZONE A - Soils are non-plastic or have low plasticity, shear strength is a function of friction angle and overburden load. Available shear strengths will increase with loading. For silt ϕ= 25° to 30°, C = 0. For fine sand ϕ= 30° to 35°, C = 0.

ZONE B - Proportion and type of inert soil will have important influence on shear strength. Strength will increase with decrease in moisture content.

M.C. 70% to 120% - S_s = 300 to 200 psf, ϕ = 12° to 15°, C = 200 psf

M.C. 40% to 70% - S_s = 600 to 300 psf, ϕ = 15° to 20°, C = 200 to 400psf

Strength tests on undisturbed samples should be made when possible.

ZONE C - Type and structure of organic material influence shear strength. S_s = 50 to 200 psf, ϕ = 12° to 15°, C = 50 to 100 psf

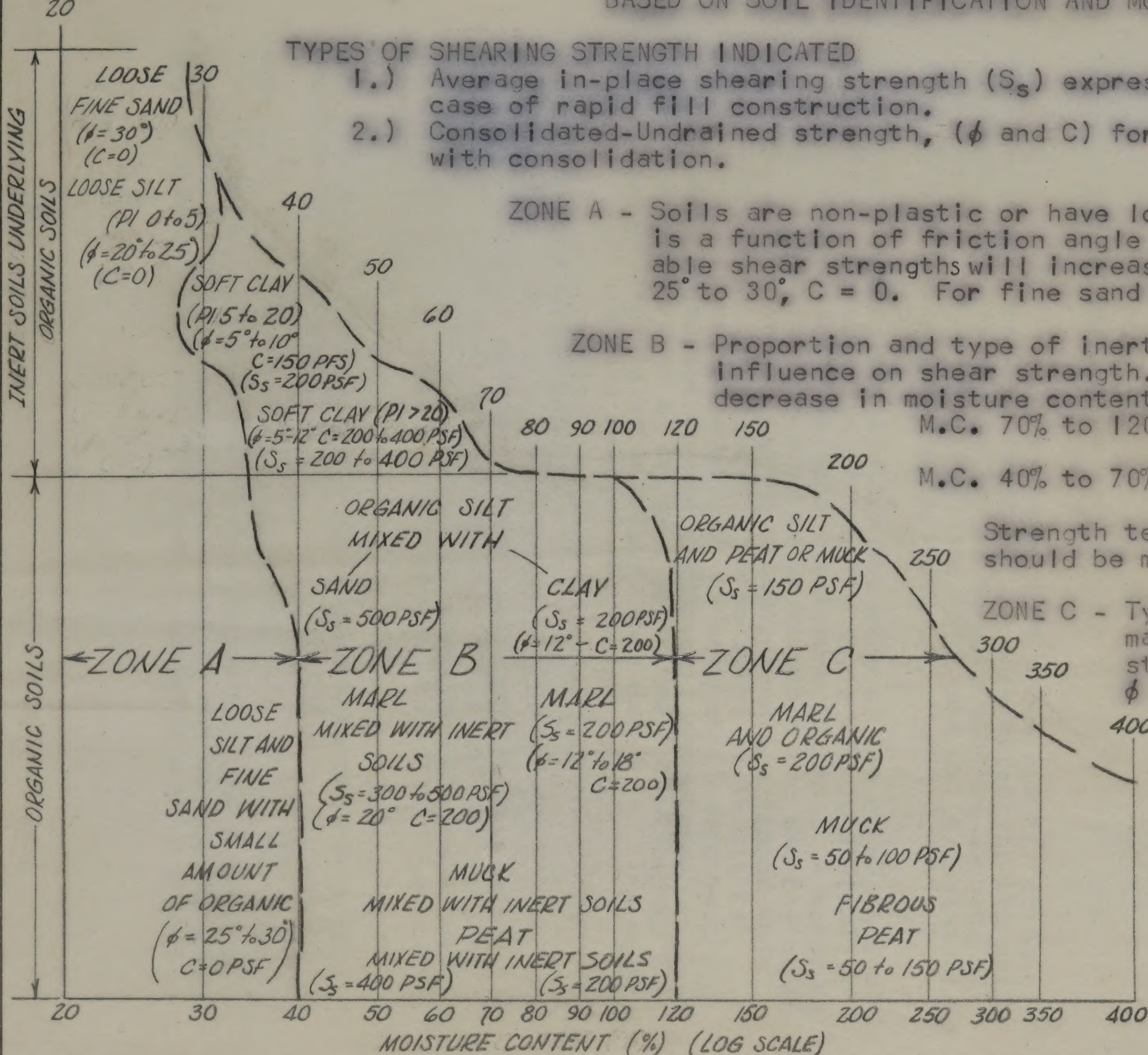

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FIGURE 2 ENGINEERING PROPERTIES OF ORGANIC SOILS	
APPROVED 19	DISTRICT NO. COUNTY
PRINCIPAL SOILS ENGINEER	DWG. NO SM 1606B

PRELIMINARY CHART FOR ESTIMATING SHEARING STRENGTHS OF SWAMP SOILS BASED ON SOIL IDENTIFICATION AND MOISTURE CONTENT

TYPES OF SHEARING STRENGTH INDICATED

1.) Average in-place shearing strength (S_s) expressed in lbs. per sq. ft. for case of rapid fill construction.

2.) Consolidated-Undrained strength, (ϕ and C) for estimating strength increase with consolidation.

ZONE A - Soils are non-plastic or have low plasticity, shear strength is a function of friction angle and overburden load. Available shear strengths will increase with loading. For silt $\phi = 25^\circ$ to 30°, C = 0. For fine sand $\phi = 30^\circ$ to 35°, C = 0.

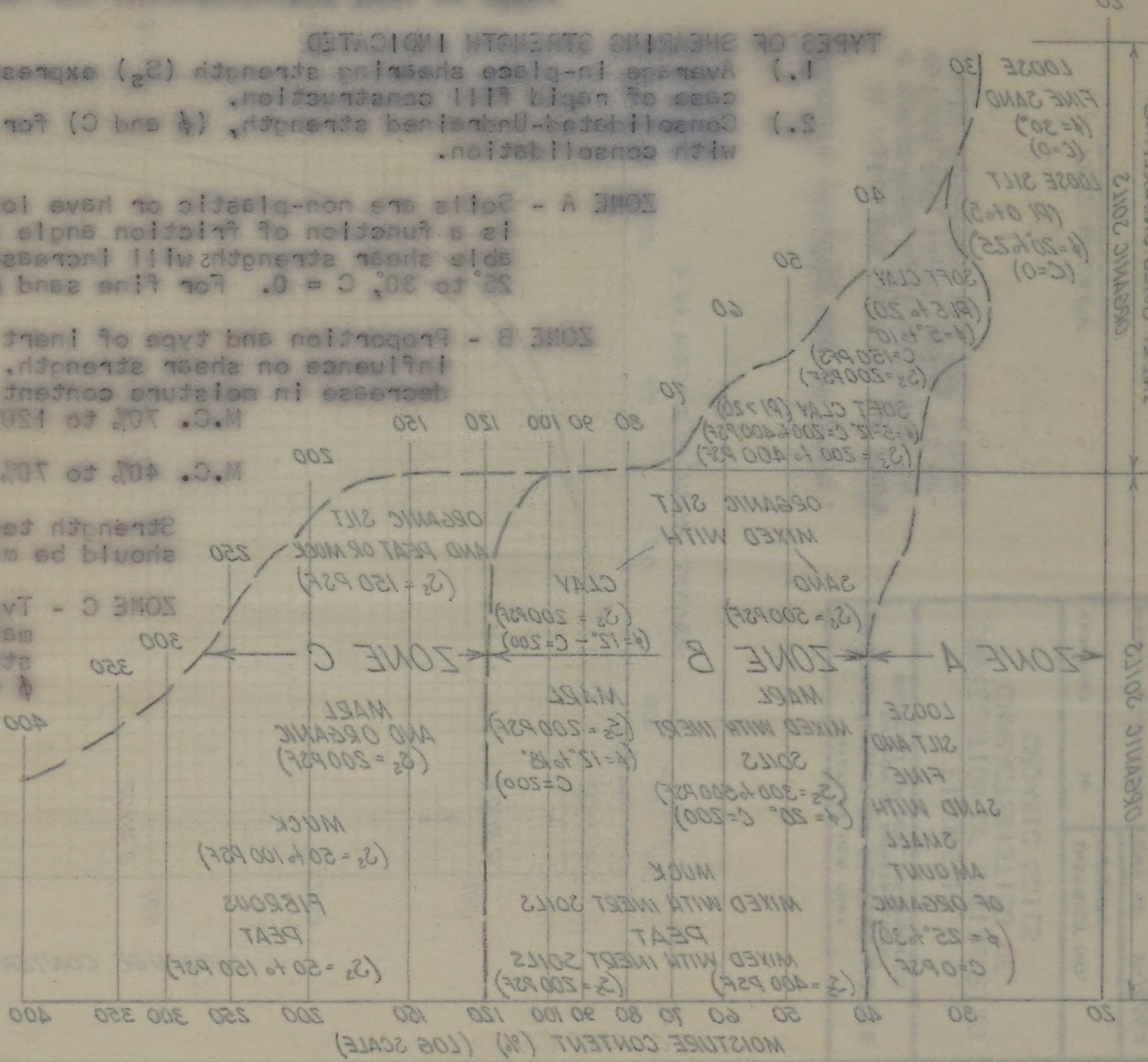
ZONE B - Proportion and type of inert soil will have important influence on shear strength. Strength will increase with decrease in moisture content.

M.C. 70% to 120% - S_s = 300 to 200 psf, $\phi = 12^\circ$ to 15°, C = 200 psf

M.C. 40% to 70% - S_s = 600 to 300 psf, $\phi = 15^\circ$ to 20°, C = 200 to 400psf

Strength tests on undisturbed samples should be made when possible.

ZONE C - Type and structure of organic material influence shear strength. S_s = 50 to 200 psf, $\phi = 12^\circ$ to 15°, C = 50 to 100 psf



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BUREAU OF SOIL MECHANICS

FIGURE 2

ENGINEERING PROPERTIES OF ORGANIC SOILS

APPROVED	19	DISTRICT NO.
		COUNTY
PRINCIPAL SOILS ENGINEER	DWG. NO.	SM 1606-B

I. INTRODUCTION

The problem of constructing highway embankments across swamp areas is frequently encountered by the soils engineer. Modern design requirements for highway systems make it necessary to cross swamp areas that were previously avoided by older highways. In urban areas new highways are purposely located in the undeveloped swamp areas to avoid high right-of-way costs. It is the responsibility of the soils engineer to determine the most economical methods of providing a suitable foundation for highway embankments in these swamp areas.

II. CORRELATION OF LABORATORY TEST DATA

Organic soils may be placed into three general categories- (1) soils that contain almost all organic material; (2) soils that contain organic material mixed with various amounts of inert soil (sand, silt, clay) and (3) inert soils that contain small amounts of organic material.

A preliminary correlation was made of the strength and consolidation properties of organic soils with the simplest classification test available - moisture content. A moisture content correlation appeared to be feasible for the following reasons: (1) Swamp soils are usually normally loaded under light overburden loads and the correlation of structural properties with moisture content is not complicated by the effects of precompression and strong soil structure. (2) The structural properties of organic soils are influenced by the proportion of organic material to inert material. The moisture content is an indirect measure of this proportion.

III. COMPOSITION OF ORGANIC SOILS

The relative volumes of each soil constituent were determined from test data on organic soils and the results are shown on Figure 1. This chart shows how the relative volumes of water, organic material, and inert soil vary with moisture content.

The curves have been divided into three general zones described as follows:

Zone C. -

In this zone the engineering properties are determined by the water and organic material and do not change rapidly with a change in moisture content. There is a very gradual

increase in the volume of inert soil with decrease in moisture content. It should be noted that a portion of the water is likely contained within the structure of the organic particles while the remainder is "free" water in the voids. Field experience and laboratory test results confirm the above conclusions and also influenced setting the lower boundary of Zone C at 120% M.C.

Zone B.-

In this zone there is a rapid increase in the proportion of inert soil with a decrease in moisture content. (eight times the rate for Zone C). The engineering properties are determined by the type and proportion of inert soil and improve with a decrease in moisture content.

Zone A.-

Soils in this zone are fine sands and silts containing small amounts of organic. The organic material does not strongly effect the structural properties of the soil.

IV. STRENGTH PROPERTIES OF ORGANIC SOILS

The results of the correlation are presented in Figure 2. Each type of organic soils is indicated for the general range of moisture contents at which it is found in nature. Inert soils underlying organic deposits are also included as these soils are usually in a loose or soft condition and sometimes present foundation problems.

V. CONSOLIDATION PROPERTIES OF ORGANIC SOILS

The results of the correlation are presented in Figure 3. Additional data is included in the appendix for estimating settlement in organic soils based on soil identification and moisture content.

VI. ESTIMATING SUITABILITY OF ORGANIC SOILS FOR HIGHWAY EMBANKMENT FOUNDATIONS.

Figure 4 is a summary of the suitability of the various types of organic soils for highway embankment foundations based on soil identification and moisture content.

This chart has been used successfully in New York State for the following types of problems:

1. Preliminary Cost Estimate of Swamp Crossings

   First the soil profile is determined by auger or retractable sampler explorations. Moisture contents tests

increase in the volume of inert soil with decrease in moisture content. It should be noted that a portion of the water is likely contained within the structure of the organic particles while the remainder is "free" water in the voids. Field experience and laboratory test results [illegible] above conclusions [illegible] influenced [illegible]

Zone 3.-

[illegible] organic [illegible] decrease [illegible] is governed by the type and proportion of inert soil and [illegible] with a decrease in moisture content.

Zone 4.-

Soils in this zone are fine sands and silts containing small amounts of organic. The organic material does not strongly affect the structural properties of the soil.

[illegible]

The results of the correlation are presented in Figure 2. Each type of organic soils [illegible] included for the general range of moisture contents [illegible] soils underlying organic deposits are also included as these soils are usually in a loose or soft condition and thus present foundation problems.

V. CONSOLIDATION PROPERTIES OF ORGANIC SOILS

The results of the correlation are presented in Figure 3. Additional data is included in the appendix for estimating settlement in organic soils based on soil identification and [illegible]

VI. [illegible]

[illegible]

Figure 4 is a summary of the suitability of the various types of organic soils [illegible] [illegible] identification and moisture content.

[illegible] been used successfully in New York [illegible]

1. [illegible] Cost Estimate of Swamp Crossings

[illegible] the soil profile is determined by [illegible] [illegible] sampler explorations. Moisture content [illegible]

are conducted on representative samples. The estimated stabilization treatment is determined from Figure 4 and quantity-cost estimates submitted to the highway designer. The designer may determine if alternate alignments around the swamp will be more economical. Often other areas of the swamp are explored to seek more favorable foundation conditions.

This method of approach allows the economics of swamp crossings to be given full consideration before the design has progressed to the stage where it becomes difficult and expensive to change the line.

2. Field Determination of Lower Excavation Limit for Unsuitable Organic Material.

Excavation of unsuitable organic material is usually carried to depths to where "firm bottom" is reached by the excavating equipment. In many swamps the unsuitable organic soil is underlain by loose silts and fine sands which appear to be "unsuitable" when excavated through water (Zone A Soils). However, if these soils are left in place they will consolidate rapidly and have adequate shear strength to support embankments. Moisture content tests on auger hole samples or relatively undisturbed samples from the excavation will allow the field engineer to determine the necessary depth of excavation. The amount of money that can be saved by using this method of excavation control can be considerable. Recently a problem of this type was encountered in the construction of a major highway in the New York City area that traversed a shallow tidal marsh 1-1/2 miles in length. The upper four feet of the swamp was unsuitable organic material that had to be removed. The organic material was underlain by four feet of clayey silt that was loose and wet but would have adequate stability to support the embankment.

When the excavation operation began, the lower four feet of material was excavated because it appeared to be "unsuitable" and excavation was carried to firm bottom. An excavation control system was set up for the field engineers. All soil with a moisture content less than 40% was to be left in place. Shallow auger holes were made ahead of the excavation operation; moisture content tests were made on the samples; and the depth of excavation was established on the cross sections. The excavation operation was completed successfully without overrunning the quantity estimate.

On this contract the cost of muck excavation and granular backfill was $3.90 per cubic yard. For this long swamp the quantity of each foot of excavation in depth over the entire area was 70,000 cubic yards. Therefore each foot in depth of overexcavation would have cost $270,000. The savings in unnecessary excavation and backfill on this project is estimated to be over $500,000.

PRELIMINARY CHART FOR ESTIMATING SUITABILITY
OF SWAMP SOILS FOR EMBANKMENT FOUNDATIONS
BASED ON SOIL IDENTIFICATION AND MOISTURE CONTENT

ZONE A - Soils underlying organic deposits usually are loose or soft and may contain small amounts of organic. Soil may appear unsuitable when excavated, but will consolidate rapidly and have adequate strength if left in place.

ZONE B - Soils may possibly be stabilized, depending on rate of consolidation, available strength, thickness of deposit, height of fill, time for surcharge treatment, waiting period before paving. Strength may vary from 200 PSF for high M.C. soils and soft clays to 600 PSF± for soils with lower M.C. containing sand and silt. Coefficient of consolidation (C_v) may vary from .03 ft.^{2} per day for fine grained soils to 1.0 ft.^{2} per day for coarser soils.

ZONE C - Unsuitable for highway foundation, unless layer is thin. Remove by excavation or displacement. Strength varies from 100 to 200 PSF. C_v varies from 0.1 to 2.0 ft.^{2} per day.

NOTE - Visual inspection of dried sample may be aid to identification.

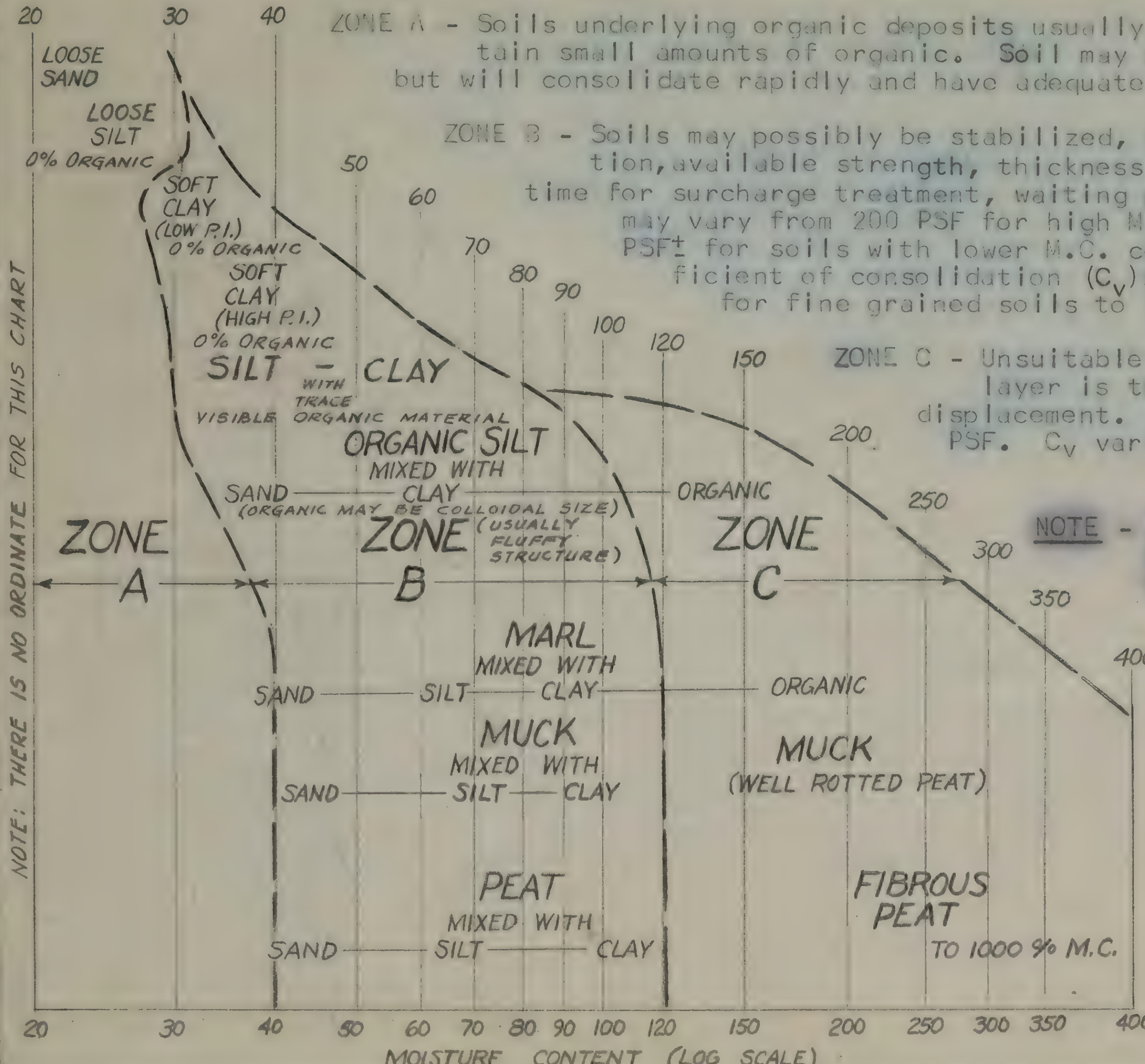

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FIGURE 1 ENGINEERING PROPERTIES OF ORGANIC SOILS	
APPROVED 10/31 1961	DISTRICT NO. M.O. COUNTY ALBANY
PRINCIPAL SOILS ENGINEER	DWG. NO SM 606A

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FIGURE # 2
ENGINEERING PROPERTIES
OF ORGANIC SOILS

APPROVED 10/31/19 61

PRINCIPAL SOILS ENGINEER

DISTRICT NO. [illegible]
COUNTY ALBANY

DWG. NO. SM [illegible] E

Method for Estimating Settlement

(2) Secondary Consolidation - Continued -

creasing organic content. There is considerable uncertainty and disagreement as to the best method of analyzing secondary settlement.

(a) Determine time for 90% consolidation.

(b) Fig. 6 shows secondary settlement expressed in percent of layer thickness. Enter appropriate curve at time for 90% primary consolidation and determine additional secondary consolidation. This method is an approximation.

(3) Time for Primary Consolidation

The basic equation for time-rate is

$$t_{mos} = \frac{TH^2}{C_v \ (30.4)}$$

T = Time Factor .848 for 90% Cons.
.197 for 50% Cons.

H = Maximum drainage path distance

C_v = Coefficient of consolidation (ft.^{2}/day) - approximate values in Fig. I. This value is very difficult to estimate

30.4 = Conversion factor to give time in months

(4) Reminder - Before going through this analysis, check stability of embankment. A settlement analysis is useless if the soil is going to be displaced.

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FIGURE 4
METHOD FOR ESTIMATING SETTLEMENT
ENGINEERING PROPERTIES OF ORGANIC SOILS

APPROVED 10/31 1961	DISTRICT NO. M.O. COUNTY ALBANY
PRINCIPAL SOILS ENGINEER	DWG. NO SM 1606D

APPENDIX

METHOD FOR ESTIMATING SETTLEMENT IN ORGANIC
SOILS BASED ON SOIL IDENTIFICATION AND
MOISTURE CONTENT

A. Basis for Correlation

(1) The consolidation characteristics of organic soils are largely influenced by the amount of organic material in the soil.
(2) The physical properties and consolidation characteristics may be correlated to moisture content without excessive variations from the average.
(3) Swamp soils are usually normally loaded and correlation is not complicated by the effects of precompression.

B. Method for Estimating Settlement

(1) Primary Consolidation

Primary consolidation is the decrease in soil volume caused by the flow of pore water from the soil under an applied load.
a) The basic formula for computing primary settlement is:

$$\Delta = \frac{HC_c}{1+e} \log_{10} \frac{P_o + \Delta P}{P_o}$$

where
Δ = Total Settlement
C_c = Compression Index - see Correlation Curve 1 - Fig. 3A
e = Void Ratio - see Correlation Curve 3 - Fig. 4A
P_o = Overburden pressure determined from Correlation Curve 2 - Fig. 3A
NOTE: For soils under water table, use submerged unit weight determined from wet density (PCF) minus 62.4 PCF. Use minimum P_o of 200 PSF for peat deposits or settlements will be unrealistically large.
ΔP = Applied embankment load

(2) Secondary Consolidation

Secondary consolidation is the continuous long-time settlement that occurs in organic soils after the primary settlement is completed. It is believed to be a readjustment of the soil structure and is sometimes described as a plastic flow. The magnitude of secondary settlement increases rapidly with in-

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FIGURE 1A
METHOD FOR ESTIMATING SETTLEMENT
ENGINEERING PROPERTIES OF ORGANIC SOILS

APPROVED 19	DISTRICT NO. COUNTY
PRINCIPAL SOILS ENGINEER	DWG. NO SM 1606 E

Method for Estimating Settlement

(2) Secondary Consolidation - Continued -

creasing organic content. There is considerable uncertainty and disagreement as to the best method of analyzing secondary settlement.

(a) Determine time for 90% consolidation.

(b) Fig. 6 shows secondary settlement expressed in percent of layer thickness. Enter appropriate curve at time for 90% primary consolidation and determine additional secondary consolidation. This method is an approximation.

This method for settlement analysis suggests using primary settlement and adding the secondary settlement that occurs after completion of primary settlement. This method has proved to be reasonably accurate for Zone A and Zone B soils (M.C. up to 120%). For high organic soils (Zone C) the secondary settlement may be the major part of the total settlement and primary settlement may be minor. Considerable work is being done by others to improve the accuracy of settlement analysis of soils with high organic content.

(3) Time for Primary Consolidation

The basic equation for time-rate is

$$t_{mos} = \frac{TH^2}{C_v \; (30.4)}$$

T = Time Factor .848 for 90% Cons.
.197 for 50% Cons.

H = Maximum drainage path distance

C_v = Coefficient of consolidation (ft.^{2}/day) - approximate values in Fig. 3. This value is very difficult to estimate

30.4 = Conversion factor to give time in months

(4) Reminder - Before going through this analysis, check stability of embankment. A settlement analysis is useless if the soil is going to be displaced.

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FIGURE 2A
METHOD FOR ESTIMATING SETTLEMENT
ENGINEERING PROPERTIES OF ORGANIC SOILS

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	COUNTY
PRINCIPAL SOILS ENGINEER	DWG. NO SM 1606F

METHOD FOR ESTIMATING SETTLEMENT IN ORGANIC
SOILS BASED ON LOAD INTENSITY AND
ORGANIC CONTENT

SETTLEMENT DUE TO CONSOLIDATION
(2) Secondary Consolidation - Continued -

[illegible]

(3) Time for Primary Consolidation

The basic equation for time is

$$t_{90} = \frac{TH^2}{C_v(86400)}$$

T = Time Factor = .848 for 90 % cons.
.197 for 50% cons.

H = maximum drainage path (inches)

C_v = coefficient of consolidation (in.^{2}/sec) - Approximate values in Fig. 5. This value is most difficult to estimate.

86,4 = conversion factor to give time in weeks

(4) Caution - [illegible]

[illegible]

FIGURE 14
METHOD FOR ESTIMATING
SETTLEMENT
ENGINEERING PROPERTIES OF
ORGANIC SOILS

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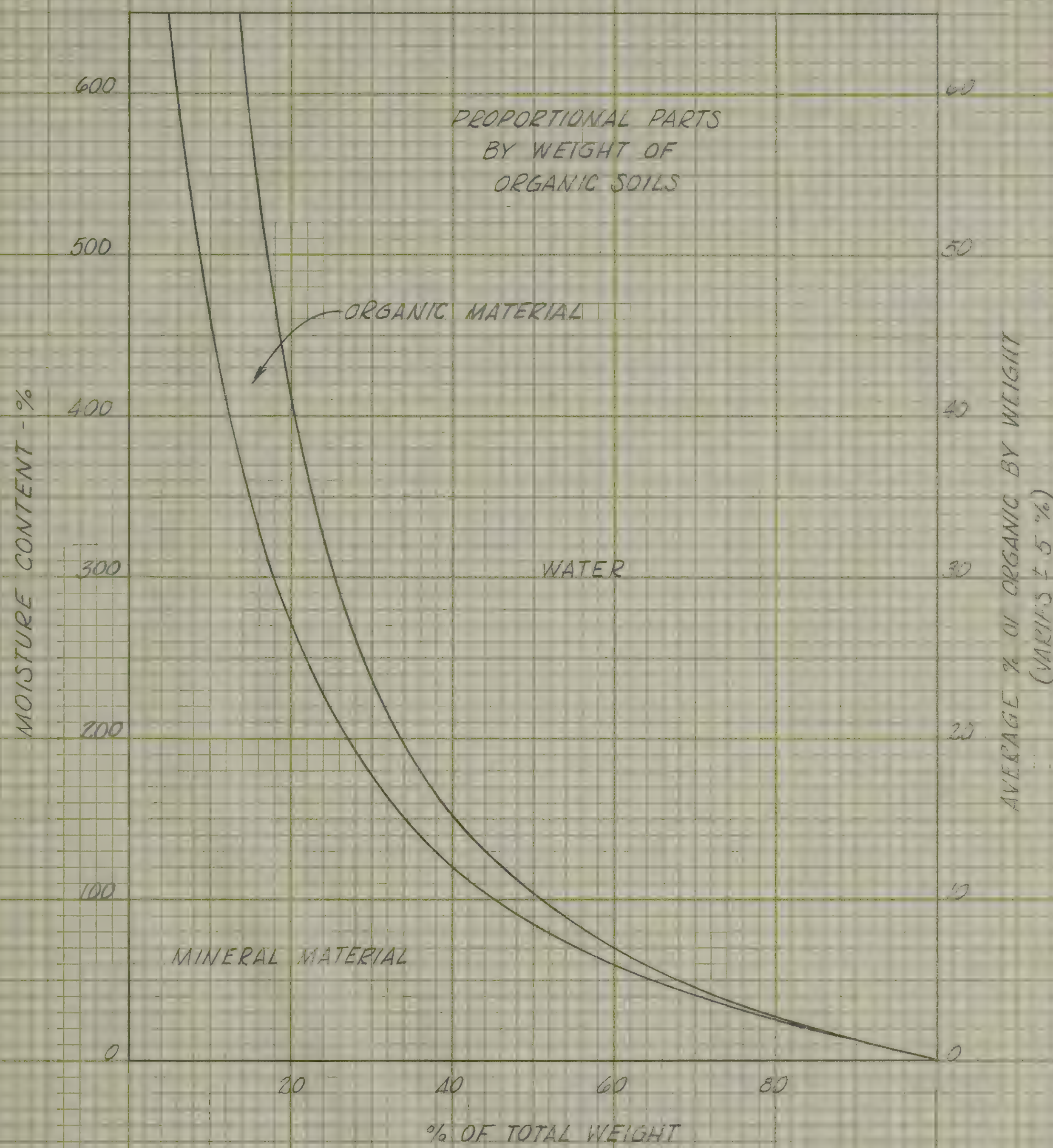
FIGURE 3A
DATA FOR SETTLEMENT
ANALYSIS - ENGINEERING
PROPERTIES OF ORGANIC SOILS

APPROVED 19
PRINCIPAL SOILS ENGINEER

DISTRICT NO. M.O
COUNTY ALBANY
DWG. NO. SM 1606 S



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ENGINEERING PROPERTIES
OF ORGANIC SOILS

APPROVED 1/9/1962	DISTRICT NO. MO COUNTY ALBANY
PRINCIPAL SOILS ENGINEER	DWG. NO SM 1606 H

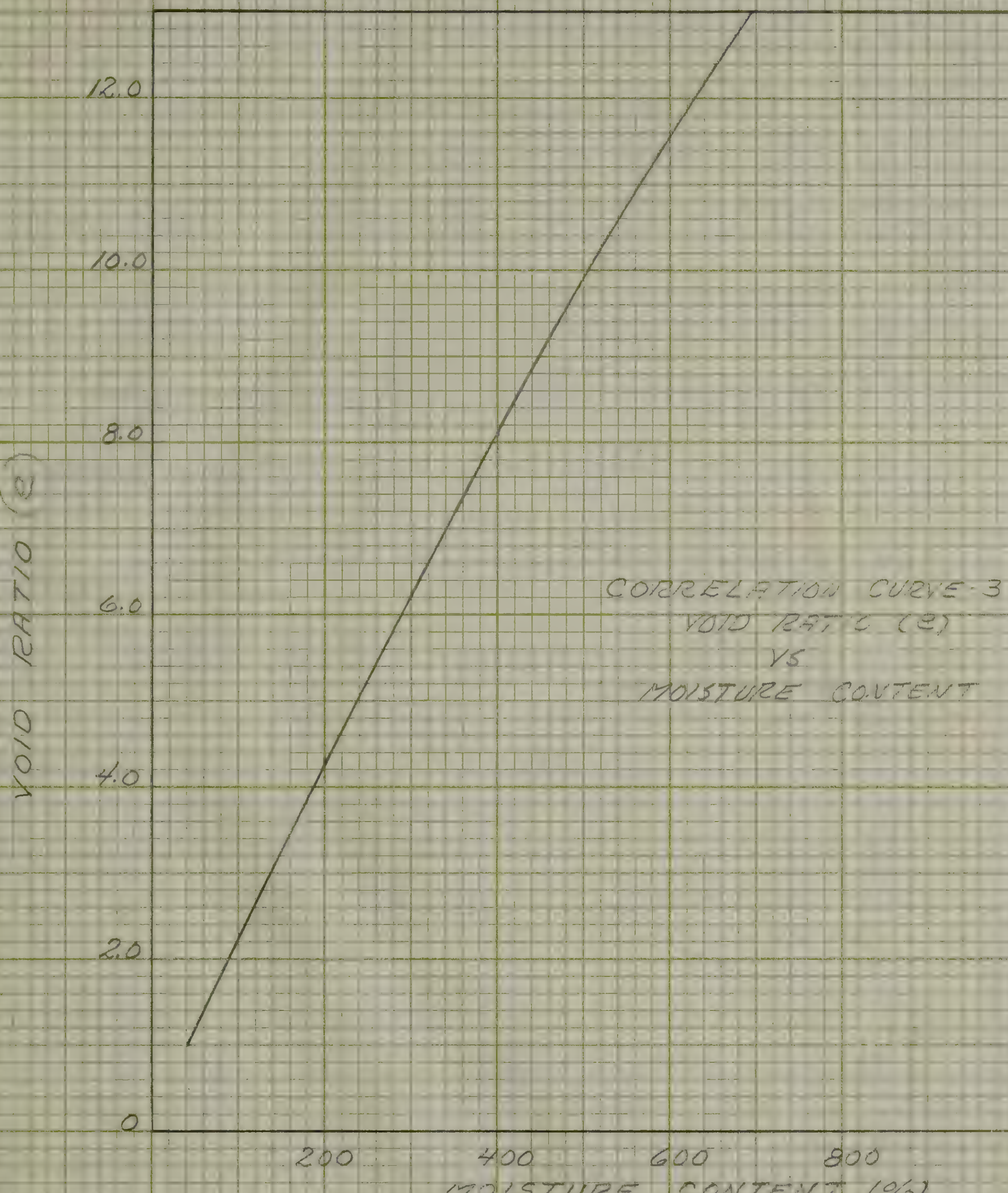

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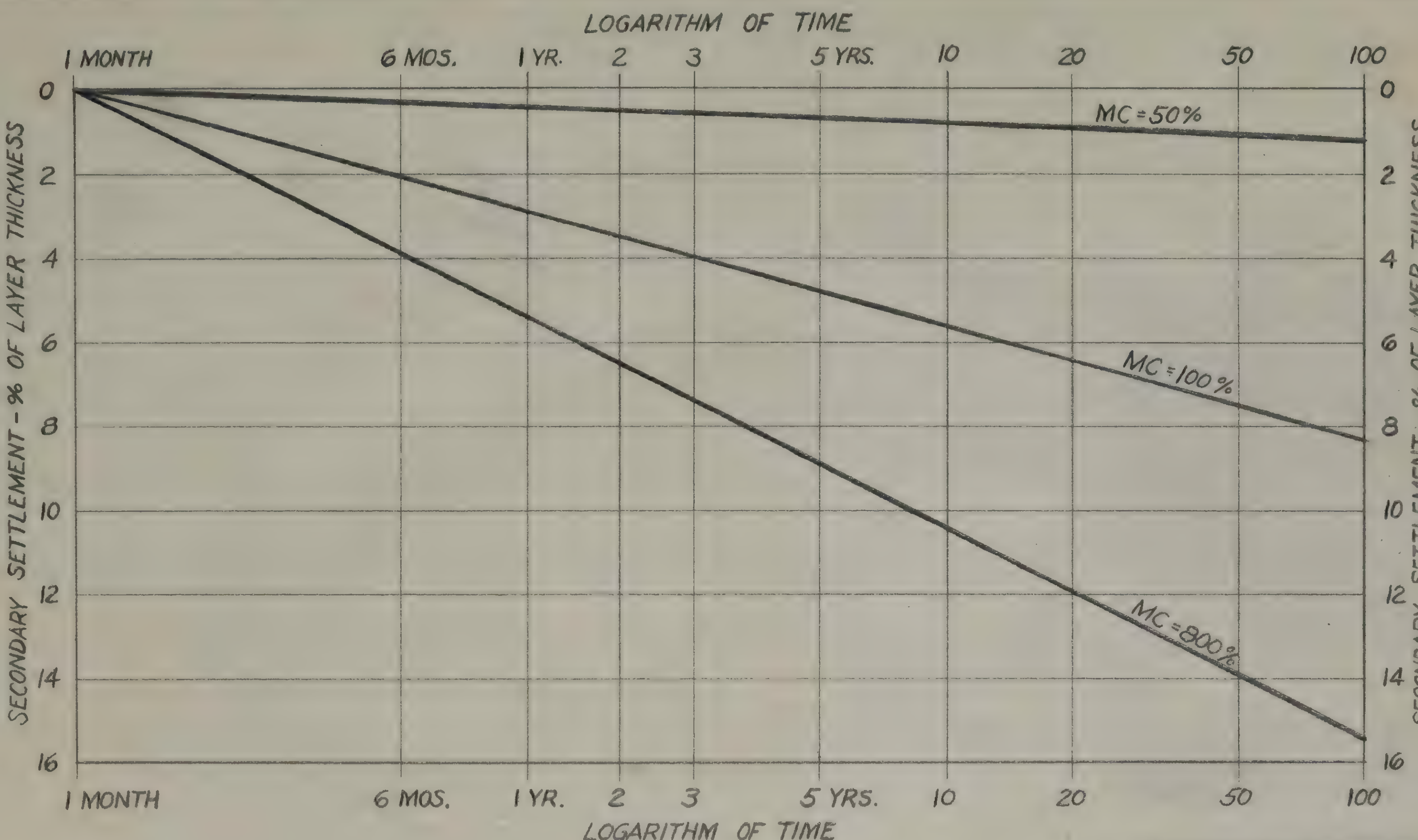
FIGURE 4A DATA FOR SETTLEMENT ANALYSIS - ENGINEERING PROPERTIES OF ORGANIC SOILS	
APPROVED 19	DISTRICT NO. M.O. COUNTY ALBANY
PRINCIPAL SOILS ENGINEER	DWG. NO SM 1606H

STATE OF NEW YORK
DEPARTMENT OF PUBLIC WORKS
BUREAU OF SOIL MECHANICS

FIGURE 4A
DATA FOR SETTLEMENT ANALYSIS - ENGINEERING PROPERTIES OF ORGANIC SOILS

DISTRICT NO.	APPROVED 19
COUNTY	
DWG NO. SM	PRINCIPAL SOILS ENGINEER



NOTE - START CALCULATING THE AMOUNT OF ANTICIPATED SECONDARY SETTLEMENT FROM THE TIME OF THE END OF PRIMARY CONSOLIDATION TO THE EXPECTED LIFETIME OF THE PROJECT.

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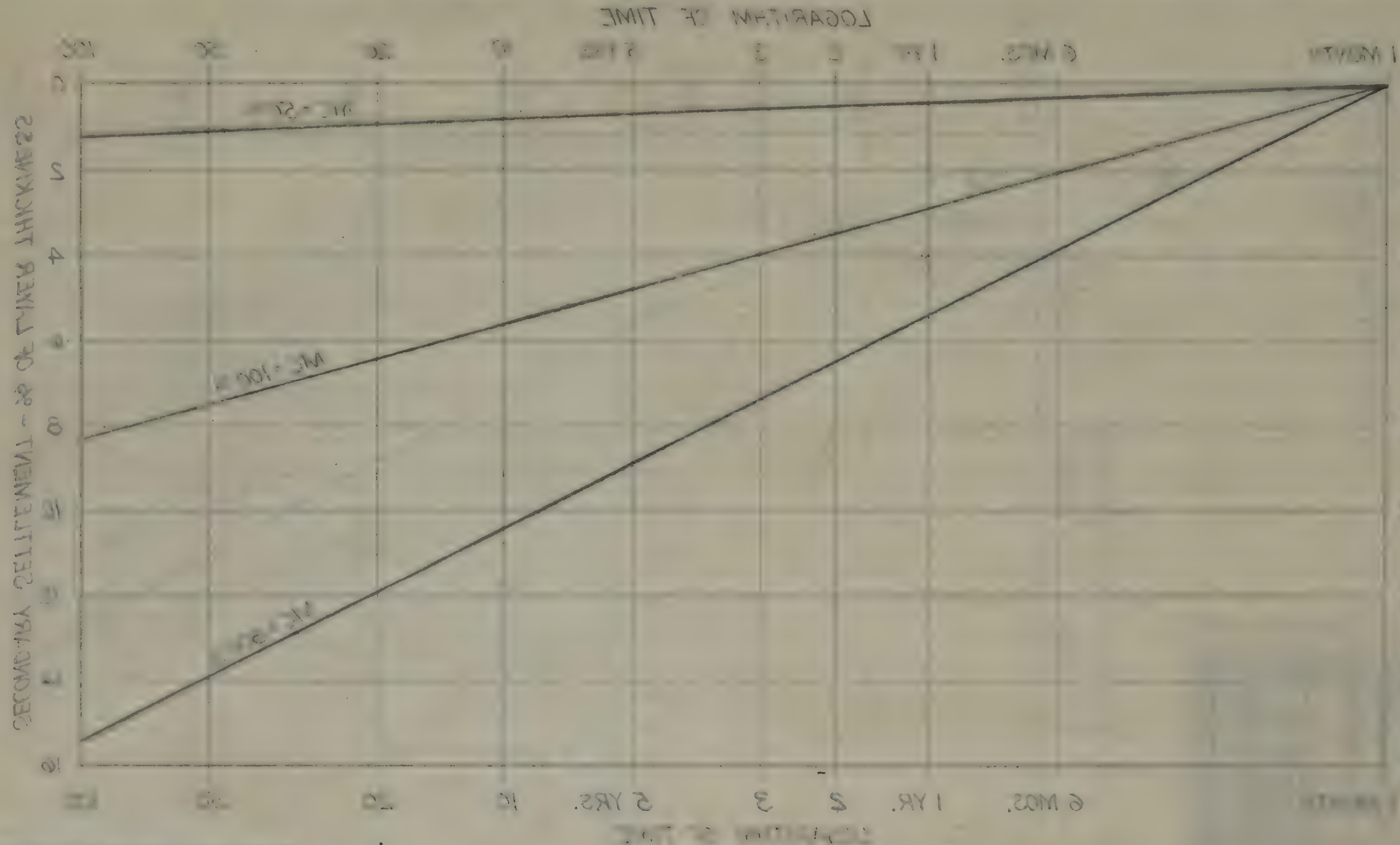
FIG. 5A ENGINEERING PROPERTIES OF ORGANIC SOILS DATA FOR SECONDARY SETTLEMENT ANALYSIS	
APPROVED 19	DISTRICT NO. MO COUNTY ALBANY
PRINCIPAL SOILS ENGINEER	DWG. NO SM 1606 J



NOTE — CHART INDICATING THE AMOUNT OF ANTICIPATED SECONDARY SETTLEMENT FROM THE TIME AFTER END OF PRIMARY CONSOLIDATION TO THE EXPECTED LIFETIME OF THE [illegible].

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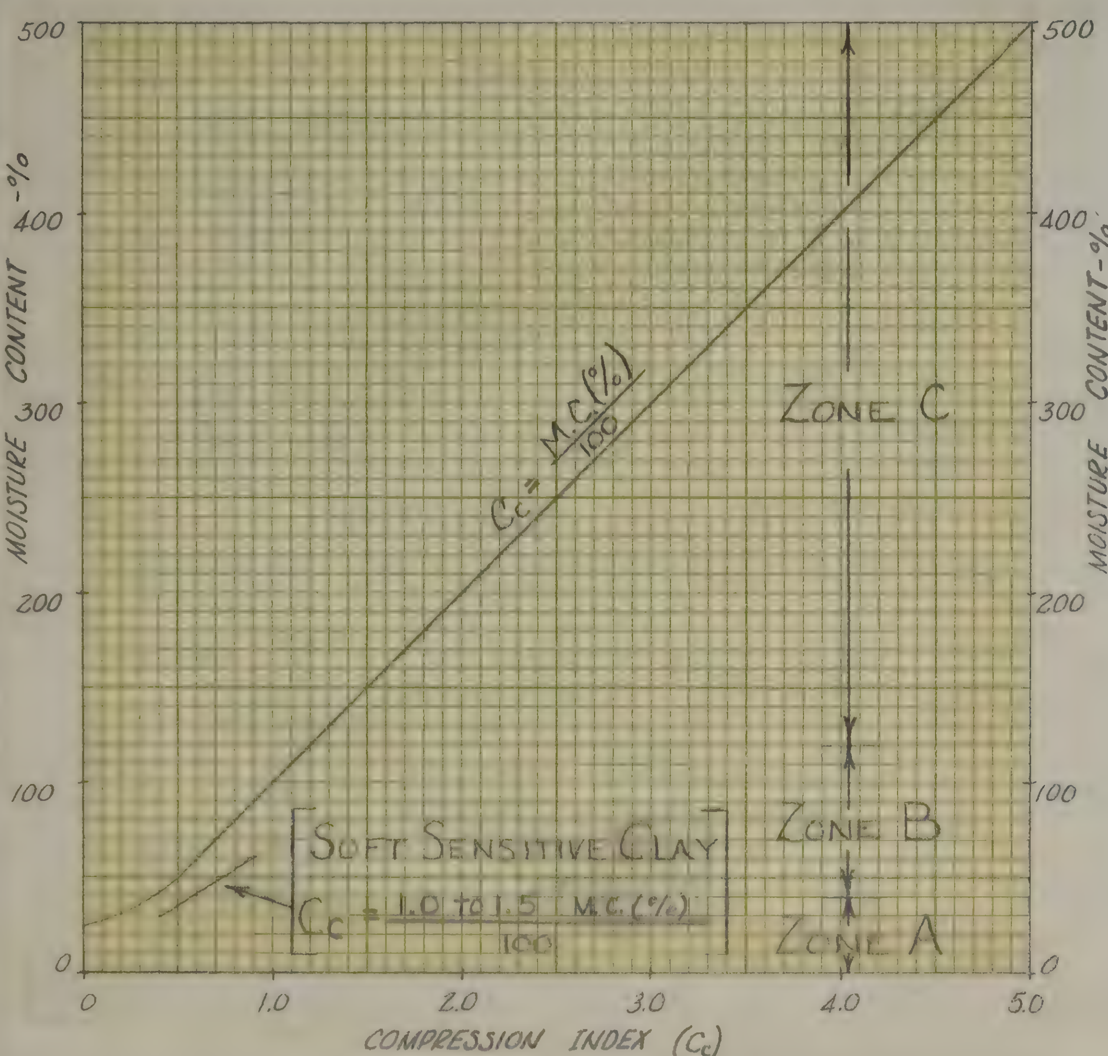
FIG. 71
ENGINEERING PROPERTIES OF ORGANIC SOILS
DATA FOR SECONDARY SETTLEMENT ANALYSIS

PRELIMINARY CHART FOR ESTIMATING
CONSOLIDATION PROPERTIES OF SWAMP SOILS
BASED ON SOIL IDENTIFICATION AND
MOISTURE CONTENT



ZONE A - Loose silts and fine sands
Compression Index (C_c)=0.1 to 0.3
Coefficient of Consolidation (C_v)=1.0 to 10.0 ft.^{2} per day.

ZONE B - Organic mixed with inert soils
Coefficient of Consolidation (C_v) will vary with type and amount of inert soil.
For organic with clay - C_v= .03 to .07 ft.^{2} per day.
For organic with silt and sand - C_v=0.1 to 1.0 ft.^{2} per day.

ZONE C - Soils with high organic content C_v=0.1 to 2.0 ft.^{2} per day depending on structure of soil.

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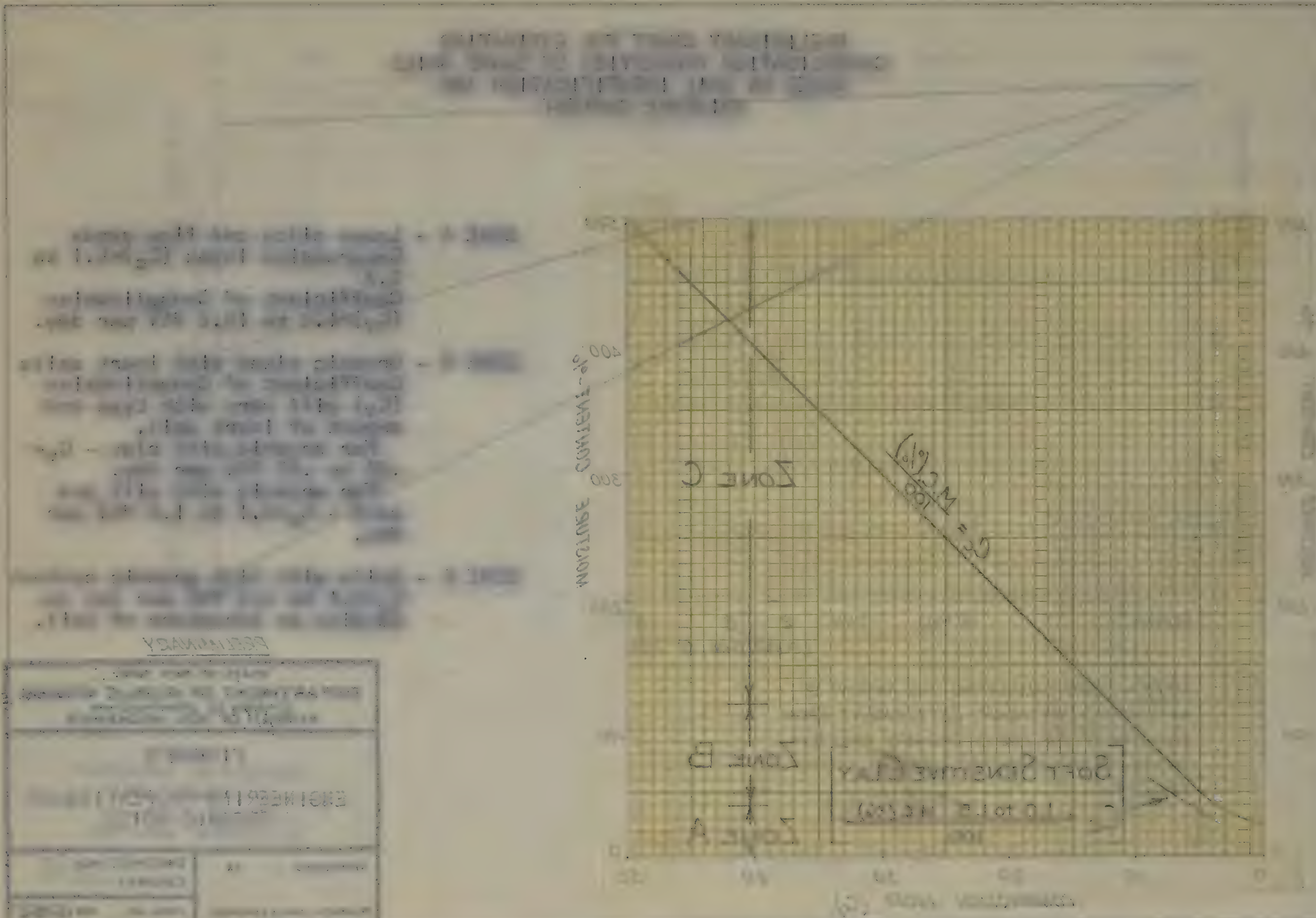
FIGURE 3 ENGINEERING PROPERTIES OF ORGANIC SOILS	
APPROVED 19	DISTRICT NO. COUNTY
PRINCIPAL SOILS ENGINEER	DWG. NO SM 1606C


MOISTURE CONTENT - %
ZONE C
ZONE B
ZONE A
SOFT SENSITIVE CLAY
PRELIMINARY

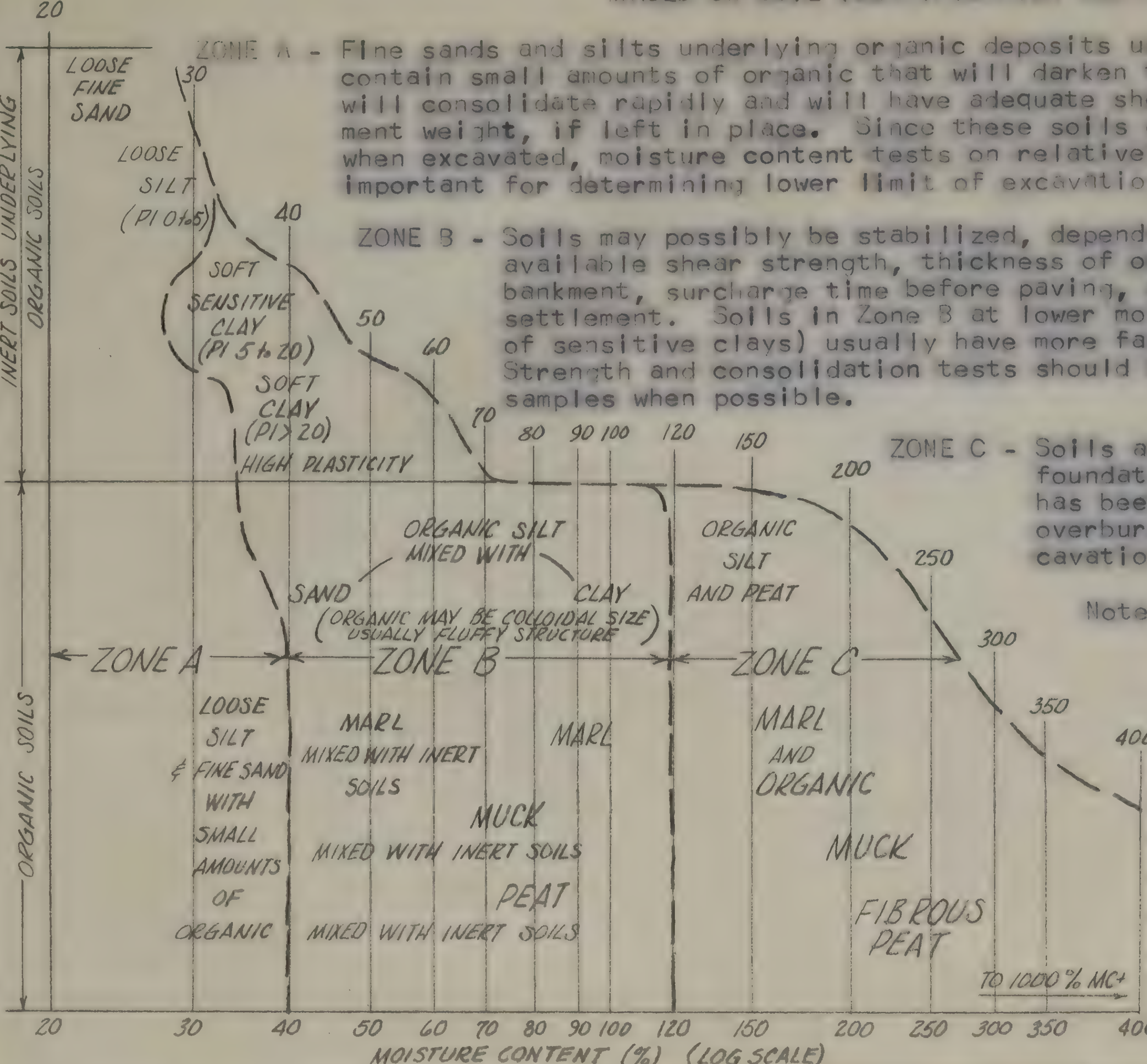
PRELIMINARY CHART FOR ESTIMATING SUITABILITY
OF ORGANIC SOILS FOR HIGHWAY EMBANKMENT FOUNDATIONS
BASED ON SOIL IDENTIFICATION AND MOISTURE CONTENT

ZONE A - Fine sands and silts underlying organic deposits usually are loose and sometimes contain small amounts of organic that will darken the soil color. These soils will consolidate rapidly and will have adequate shear strength to support embankment weight, if left in place. Since these soils often appear to be "unsuitable" when excavated, moisture content tests on relatively undisturbed samples will be important for determining lower limit of excavation in field.

ZONE B - Soils may possibly be stabilized, depending on rate of consolidation, available shear strength, thickness of organic deposit, height of embankment, surcharge time before paving, and allowable post-construction settlement. Soils in Zone B at lower moisture contents (with exception of sensitive clays) usually have more favorable engineering properties. Strength and consolidation tests should be conducted on undisturbed samples when possible.

ZONE C - Soils are <u>unsuitable</u> for embankment foundations unless deposit is thin or has been precompressed by existing overburden. Otherwise remove by excavation or displacement.

Note: A visual inspection of the sample will aid in identification of soil.



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BUREAU OF SOIL MECHANICS

FIGURE 4

ENGINEERING PROPERTIES OF ORGANIC SOILS

APPROVED 19	DISTRICT NO. COUNTY
PRINCIPAL SOILS ENGINEER	DWG. NO SM 1606 D

MEMORANDUM
DEPARTMENT OF TRANSPORTATION

DATE March 10, 1976

SUBJECT OVERSTRESS ANALYSIS ON SENSITIVE CLAYS

FROM R. L. Gemme

TO V. C. McGuffey

As we discussed, I have prepared the following guide to running overstress stability analysis on sensitive clays.

<u>Overstress Stability Analysis</u>

<u>Applicability</u>

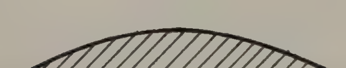
Progress overstress analysis when clay is sensitive and shearing stress at any point exceeds shearing strength.

<u>Procedure</u> - 1. <u>Check for Clay Sensitivity</u>

- High moisture content clays with liquid limit exceeding moisture content by at least 10%.
- Unusually sharp break in the shear stress-strain curve.
- Ultimate strength is less than 80 percent of peak strength.
- Larger than normal pore pressure build-up during shear strength test.

2. <u>Check for Overstress</u>

- Plot shear stress with depth from chart on page 5-12 of design manual and compare to shearing strength with depth. The zone of overstress at time equals zero after embankment construction is where the shearing stress exceeds the shearing strength. This zone of overstress increases with time due to loss of shearing strength (ultimate strength) in the overstressed zone. The loss in strength continues until the net difference between the shearing stress and ultimate shearing strength is equal to zero (see Fig. No. 1) i.e. where

Area  = Areas  + 

From experience ultimate shearing strength has been found to be in the order of 0.75 times the maximum shearing strength for sensitive New York clays. The limits of overstress increase with time as indicated above from undrained stress distribution. However consolidation and strength gain also increase with time depending on the rate of embankment construction and soil coefficients of consolidation. This tends to decrease the zone of overstress with time. These two rate processes are opposite in effect. To complicate matters comparatively large strains occur in the overstressed zone causing decrease in permeability which affects consolidation and ultimate strength gain.

Since sensitive soils are usually very slow consolidating and it is difficult to determine ultimate strength gain effects, strength increase due to consolidation should be neglected in the final analysis.

3. Progress overall stability analyses by the Bishop method utilizing design shear strength as obtained in Figure No. 1.

References, Maximum Shearing Stress Charts =

1) BSM Design Book Pg. 5-12
2) Plastic Charts, BSM Foundation Design Section Files
3) Navdocks pg. 7-5-1
4) Burmister Charts, HRB, Proceedings of 35th Annual Meeting, 1956
6) The Application of Theories of Elasticity and Plasticity to Foundation Problems. Leo Jurgenson, Journal of the Boston Society of Civil Engineers, July, 1934.
7) Poulos, H.G. & E.H. Davis "Elastic Solutions for Soil and Rock Mechanics," John Wiley & Sons, 1974.

RLG:MF

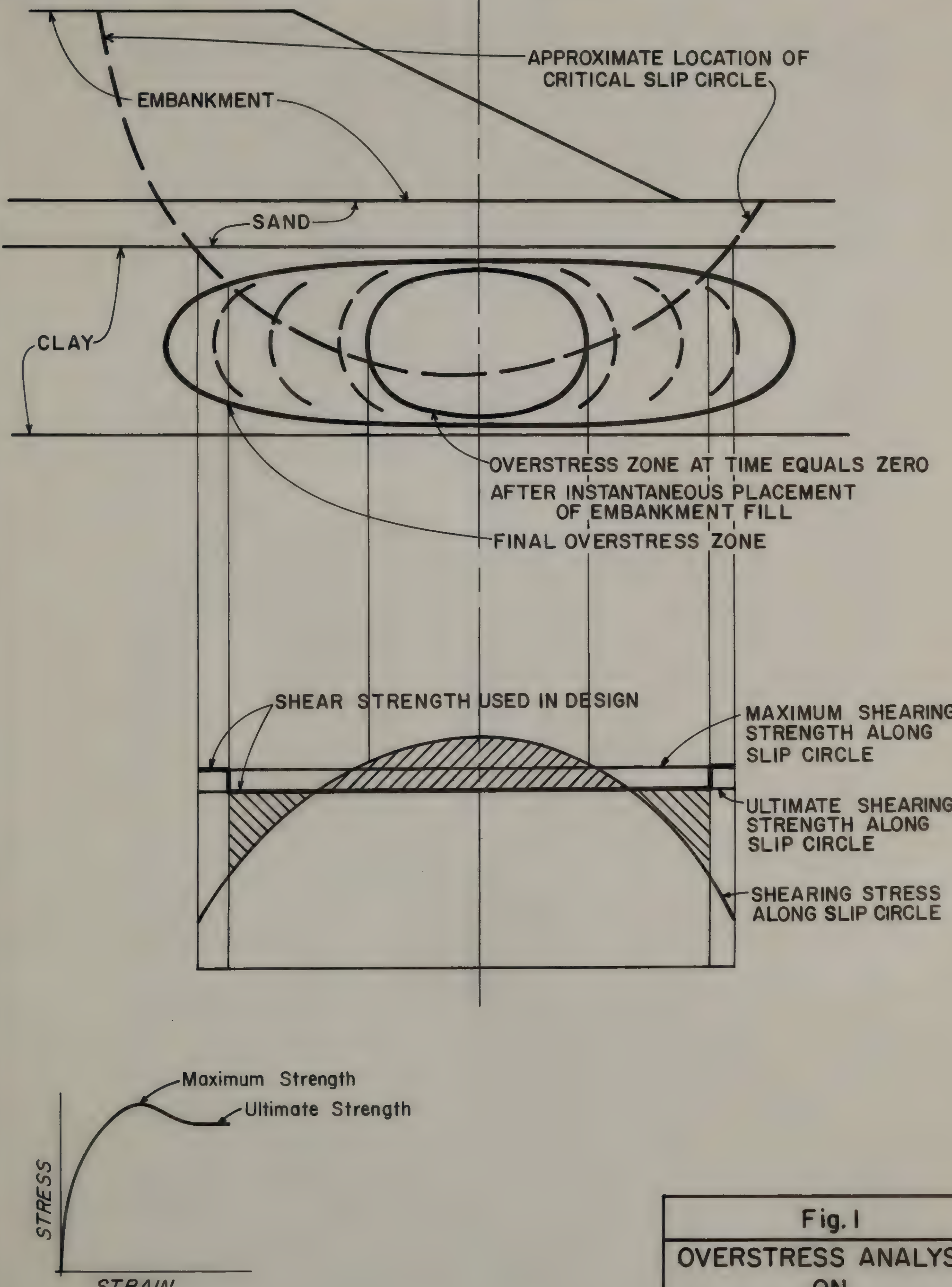


Fig. 1

OVERSTRESS ANALYSIS ON SENSITIVE CLAYS

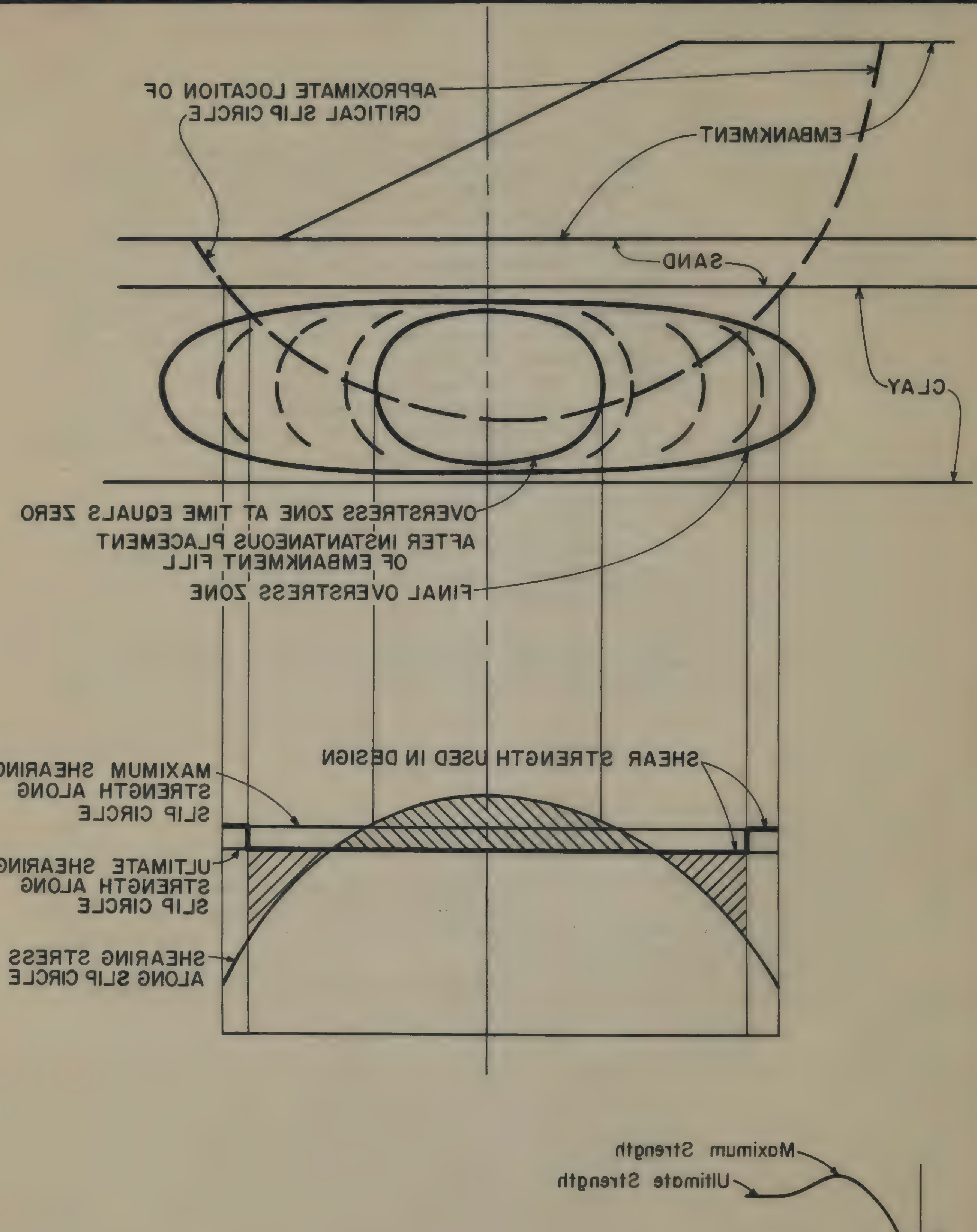
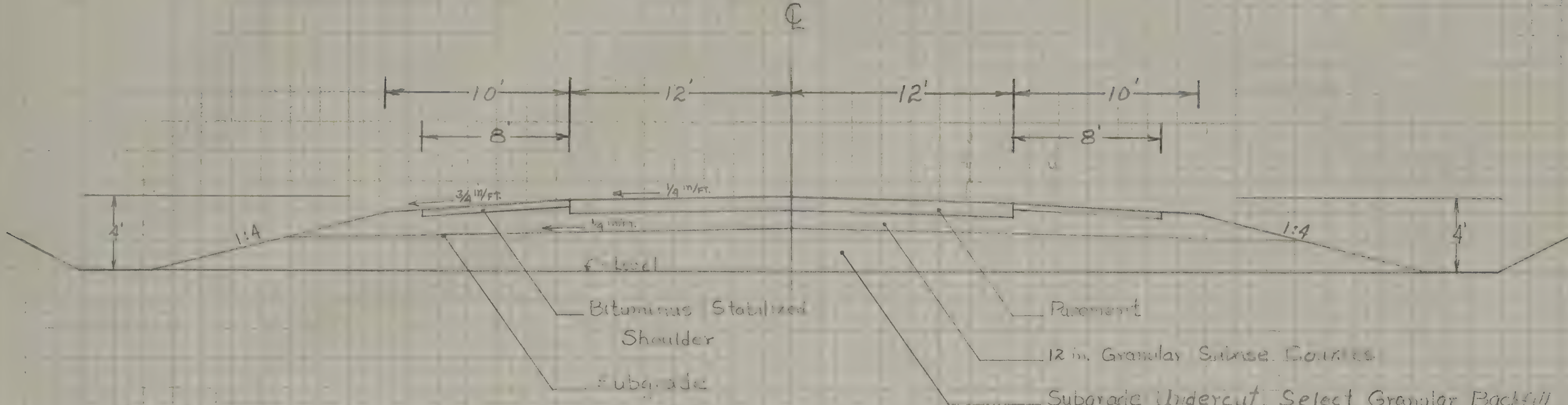
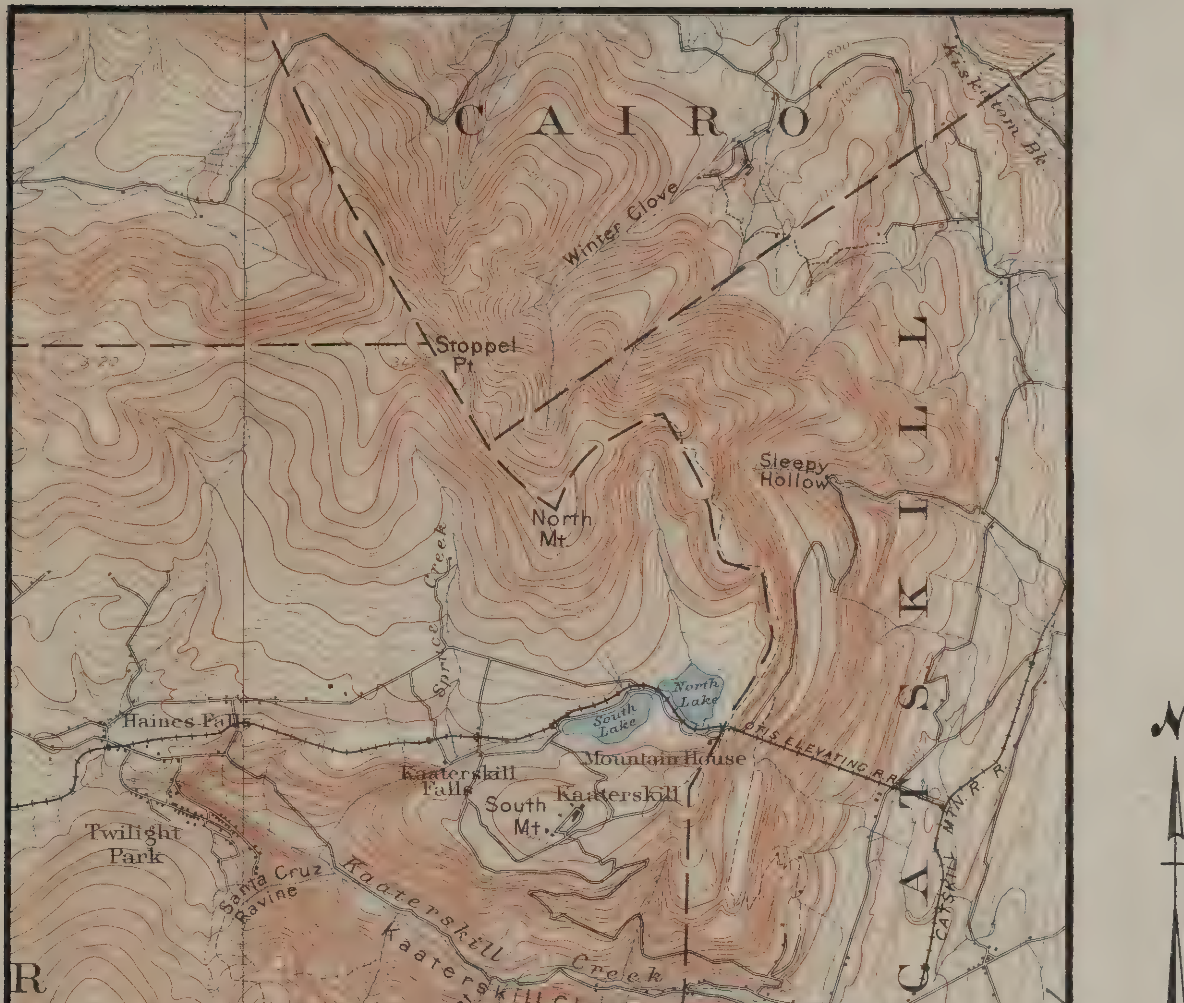


Fig. 1

OVERSTRESS ANALYSIS
ON
SENSITIVE CLAYS



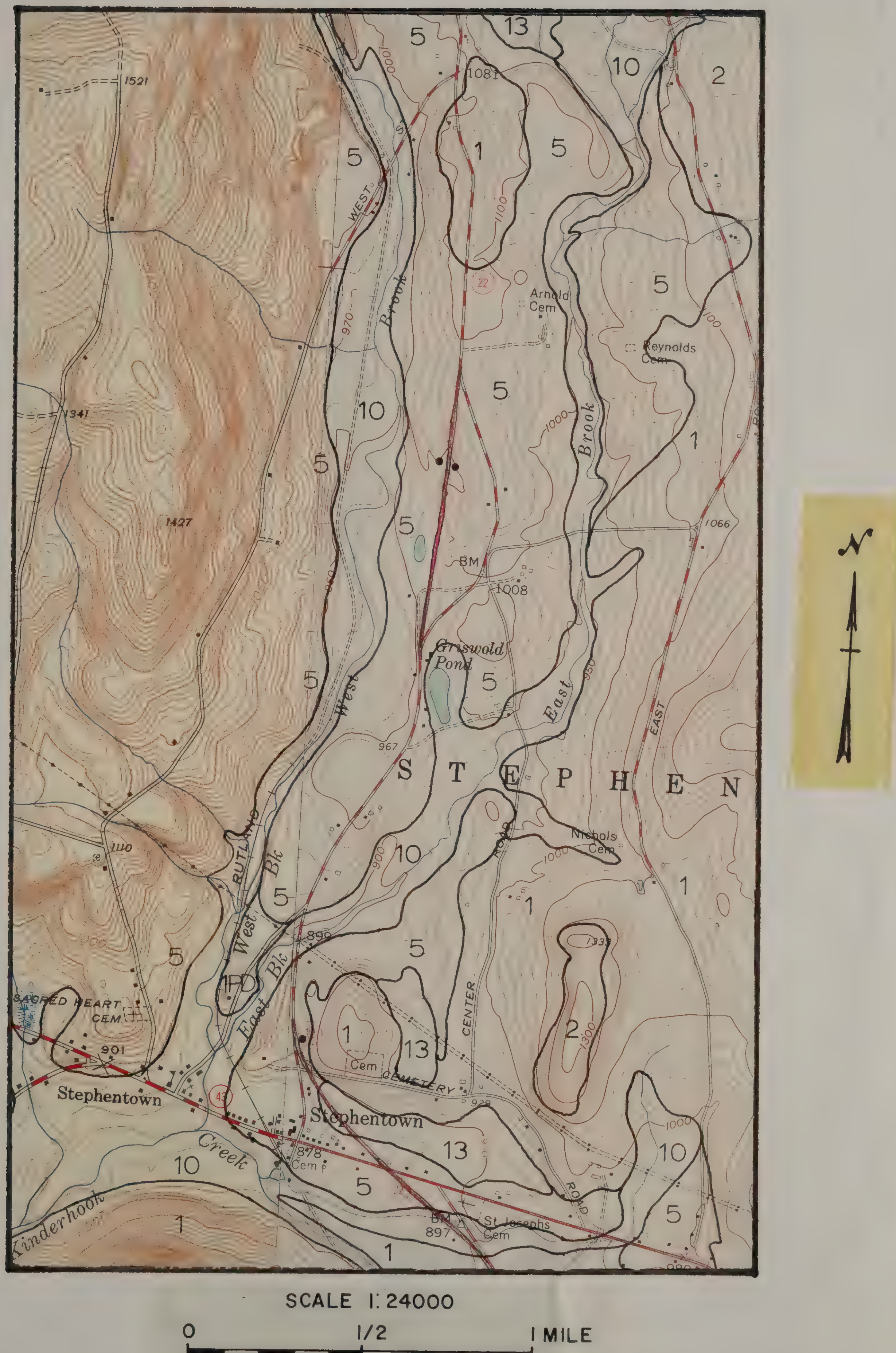
TYPICAL SECTION
SUBGRADE UNDERCUT
scale



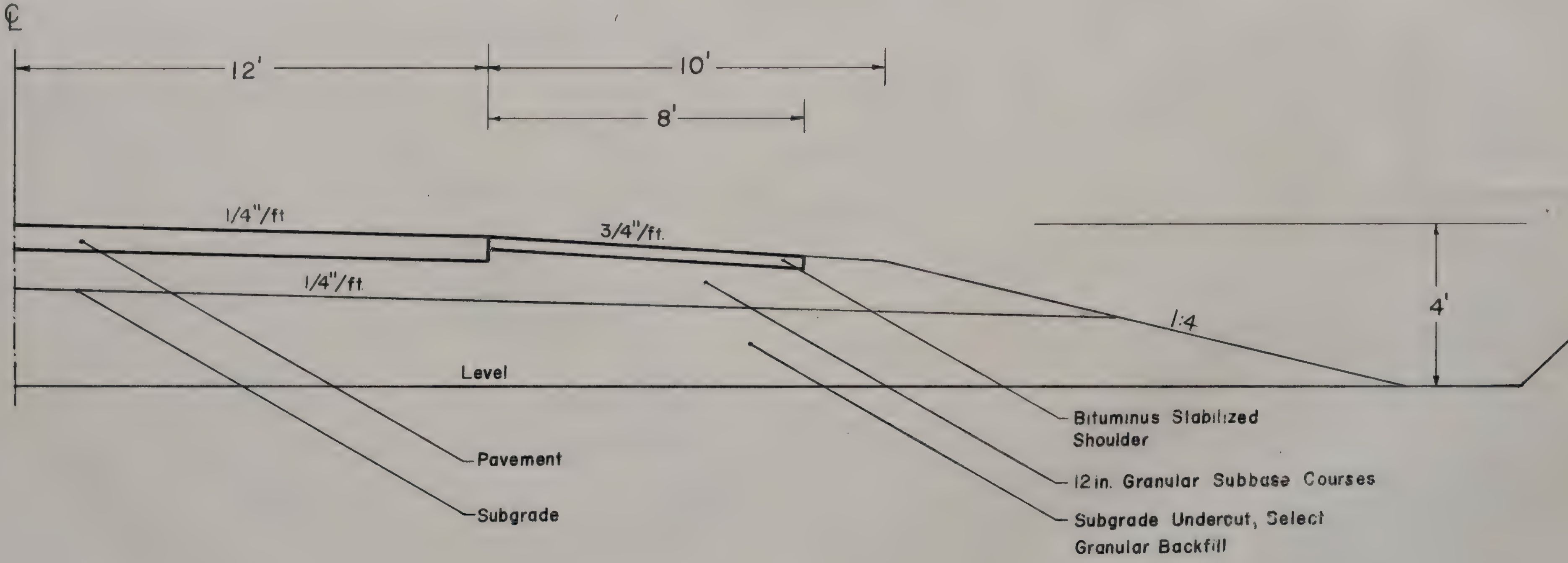
SCALE 1:24000

0 1/2 1 MILE

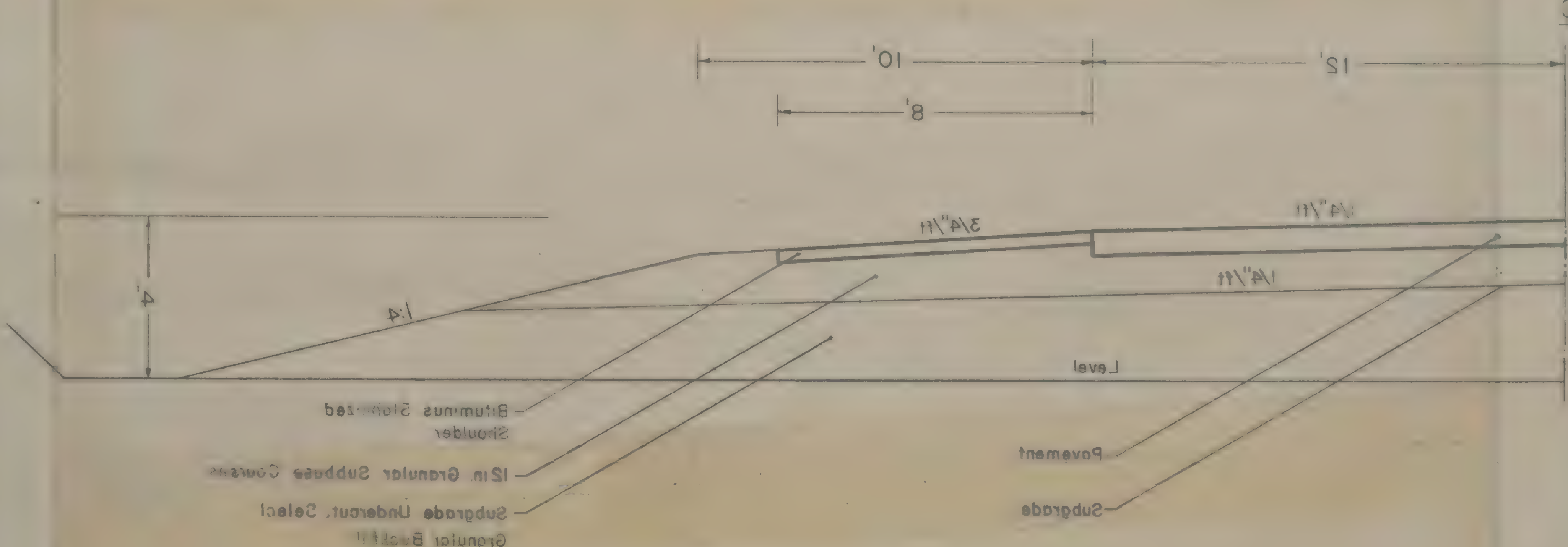
CONTOUR INTERVAL FEET



STEPHEN
Stephentown
Stephentown
Griswold Pond
Arnold Cem
Reynolds Cem
Nichols Cem
SACRED HEART CEM
St Josephs Cem
Cem
West Brook
East Brook
West Bk
East Bk
Kinderhook Creek
RUTLAND
WEST
EAST
CENTER ROAD
CEMETERY
ROAD
BM
1521
1341
1427
1081
1066
1008
1110
967
899
901
878
897
929
1333
SCALE 1:24000
0
1/2
1 MILE



TYPICAL SECTION
SUBGRADE UNDERCUT
SCALE $\frac{1}{4}"$ = 1 ft



TYPICAL SECTION
SUBGRADE UNDERCUT
SCALE 1/4"=1ft

GENERALLY - EMERGENCIES ALONG LAKE CHAMPLAIN

Slide 1

GLACIATED 1,000,000 YRS AGO

THE SOIL DEPOSITS WER CONTROLLED BY THE GLACIER

1 - TILL UNDER ICE

2 - SANDS & GRAVELS - AREAS OF HIGH VELOCITIES IN ICE MELT

3. SILTS & SAND - LOWER WATER VELOCITIES FROM ICE MELT

4. SILT & CLAY - LAKES OR NO WATER VELOCITY

- SILT & CLAY - GENERALLY ~~[illegible]~~ ENGINEERING PROBLEMS

Slide 2

196~~[illegible]~~ SPAR MILL BAY LOCO. 20 FT

Slide 3

MUDWAVE - 150 FT FROM TRACK

LAKE BOTTOM RAISE 12-15 FEET

THE AREA ~~WERE THE SLIDE OCCURRED~~ WAS APPARENTLY MOVING SLOWLY BEFORE THE SLIDE SINCE

① THE TRACKS WERE RAISED TWICE IN 4 DAYS

② DERAILMENT - APPARENLY CAUSED BY MORE SETTLEMENT ~~[illegible]~~

THE SLIDE OCCURRED SUDDENLY BENEATH WORK TRAIN THAT HAD BEEN IDLING ABOUT IN THE THE AREA ~~AFTER~~ AFTER ~~[illegible]~~ REMOVING THE WRECKAGE FROM THE DERAILMENT

Slide 4

PLAN - LAND SLIDE TOPO - POSSIBLY 1000 YRS OLD

TRACKS - 100 FT FROM LAKE

DISPLACED SHORE

Slide 5

SECTION WE ~~ASSUME~~ FEEL THAT THE SLIDE WAS ~~PROBABLY~~ ~~CAUSED~~ ~~CAUSED~~ ACCELERATED BY THE ENGINE VIBRATIONS. ~~THESE VIBRATIONS~~ THE ~~LIQUIFIED OR A SILT LAYER~~ ON THE SUSUPTIBLE SILT LAYERS.

VARVED OR LAYERED

PROBABLY CAUSED THE SILT TO BEHAVE AS A LIQUID WHICH ~~CAUSING~~ CAUSED THE EMBANKMENT TO DROP DOWN -

SLIDE HOROZONTALLY AND RAISE THE
LAKE BOTTOM UP

SINCE THE RR WANTED THE TRACKS ~~TO~~
OPEN ASAP THERE WAS NO TIME
FOR DETAILED ANLYSES
THEREFORE THIS BERM WAS ESTIMATED
~~BASED~~ ON EXPERIENCES IN HIGHWAYS
AND ~~REPORTEDLY~~ THE AREAS HAS BEEN STABLE SINCE

PORT KENT

SLIDE 6 THIS AREA ~~BUILT IN 1870~~ IS IN A
SAND DEPOSIT @ MOUTH OF A GLACIAL RIVER
ENDING AT THE LAKE

THE RR WIDENED THE TOP OF THE ESCARPMENT
IN THE 1880'S AND THE AREA WAS STABLE
FOR YEARS UNTIL IN 1971. ~~WHEN THE~~

SLIDE 7 IN 1971 CONDITIONS
SPRING CONDITIONS
Ground water flowed into the fill which
eventually sloughed
RR BEGAN PLACING EMERGENCY FILL
AND CONTACTED ~~US~~ THE DEPT
WHEN ARRIVED - THE EMERGENCY FILL ~~WAS~~
LOCALLY AVAILABLE WAS ~~FOUND TO BE~~ A WET SILTY SAND AND
was flowing in to the lake
WE SUGGESTED LT WT FILL

SLIDE 8 → RR HAD GONDOLA'S AND STONE
BALLAST
THIS PROVIDE BOTH A
① Reduction IN WT OF FILL which
Stopped THE SAND FROM FLOWING
② AND A PERVIOUS DRAINAGE MEDIUM FOR
THE GROUND WATER FLOW
THIS AREA HAS BEEN STABLE SINCE

Slide 9

IN 1975 IN THIS AREA
THERE WAS A SHEAR FAILURE
NOTE CIRCULAR ARC which is TYPICAL
of SOFT SILT & CLAY FOUNDATION CONDITIONS

This slide was caused by
① AN "INCREASE IN" LAKE LEVEL - Noted by Tree
CAUSING ~~MORE~~ EROSION AT THE TOE
of SLOPE coupled with weak Foundation Soils
~~and ② the spring conditions where the soil becomes heavier due to increase~~
of saturation

We had time to analyze this situation
because the trains could operate
the analyses showed that the most economical
solution to this problem was to flatten the
slope and protect the toe from
future erosion with Rip Rap.

Currently, we are doing 100 mile pilot study
to Locate and suggest remedial treatments
for soils related problems

Few TYPICAL PROB

Slide 10

ROCK EMBANKMENTS
INTERMITTEN ~~FLOWS~~ DRAINAGE THRU THEM
CAPPED WITH CINDERS AND/OR BALLAST

Slide 11

① WATER - RAIN REMOVES FINES FROM CINDERS
② INTERMITTENT CROSS FLOWS ~~[illegible]~~ REMOVES FINES
FROM ROCK FILL
~~We~~ WE SUGGEST ~~ANTICIPATE~~ THAT ~~if we can~~
The Rock ~~plane~~ be LOCATED ~~THE~~ and EXPECT THAT
AN IMPERMEABLE SEAL CAN BE
PLACED possibly CEMENT OR CHEMICAL

Slide 12

CLAY SHEAR FAILURE
EVENTUALLY will cross tracks
Requires borings and analysis
Can be corrected with a berm

Slide 13 EROSION ALONG LAKE MILES

Slide 14 RR corrected as we did in Highways by placing RIP RAP

Slide 15 Shows bleaching fines from embankment this was what ~~caused~~ led us to the development of graded filter behind ~~Rip Rap~~ RipRap to prevent this from occurring

— — LAST EXAMPLE I would LIKE TO CONCLUDE by saying

THE objective of This pilot Study is

TO APPLY The Principles of SOIL TECHNOLOGY

IN AN effort TO REDUCE THE YEARLY MAINTENANCE

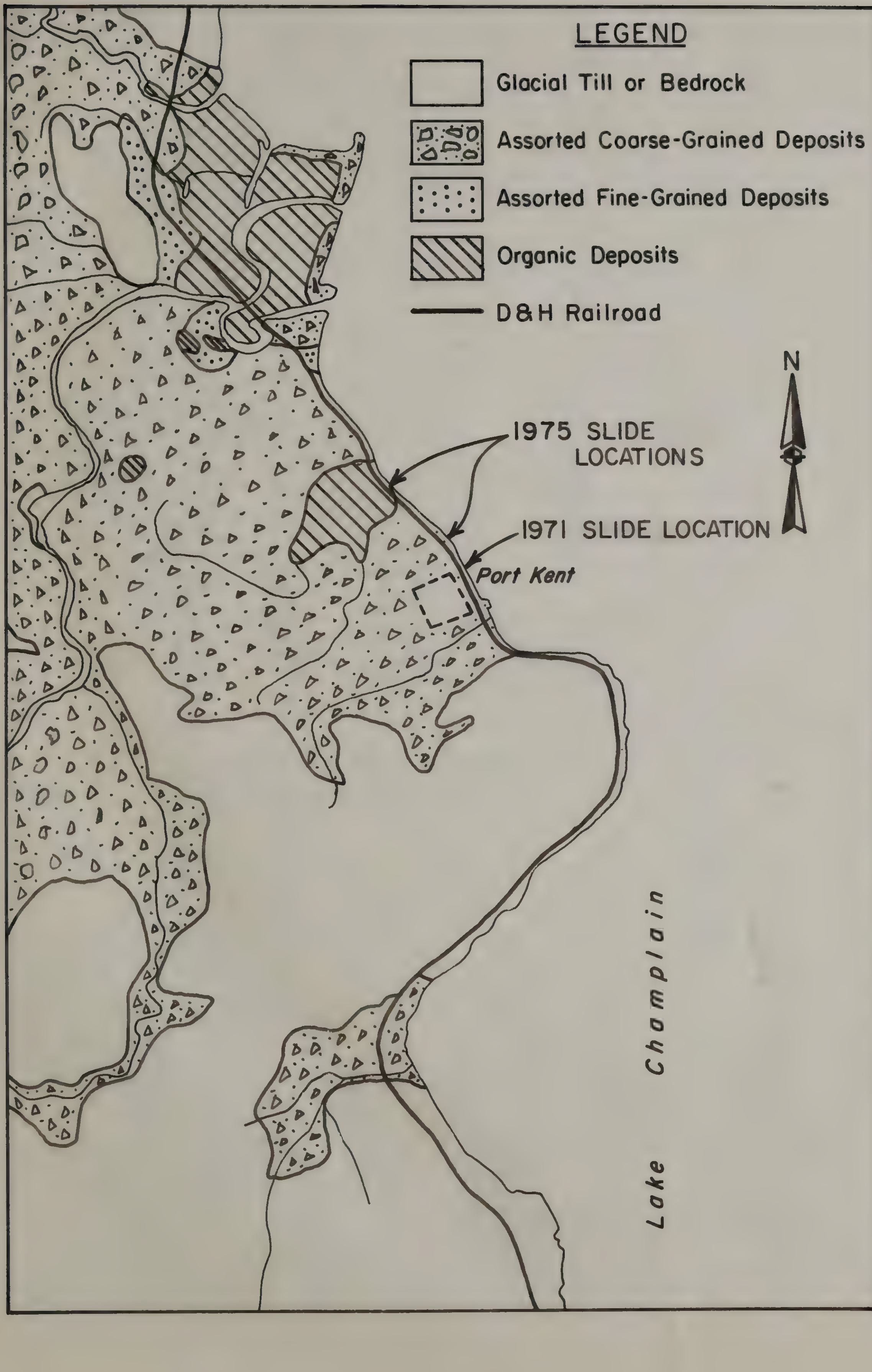
COSTS of THE RAILROAD. However THE

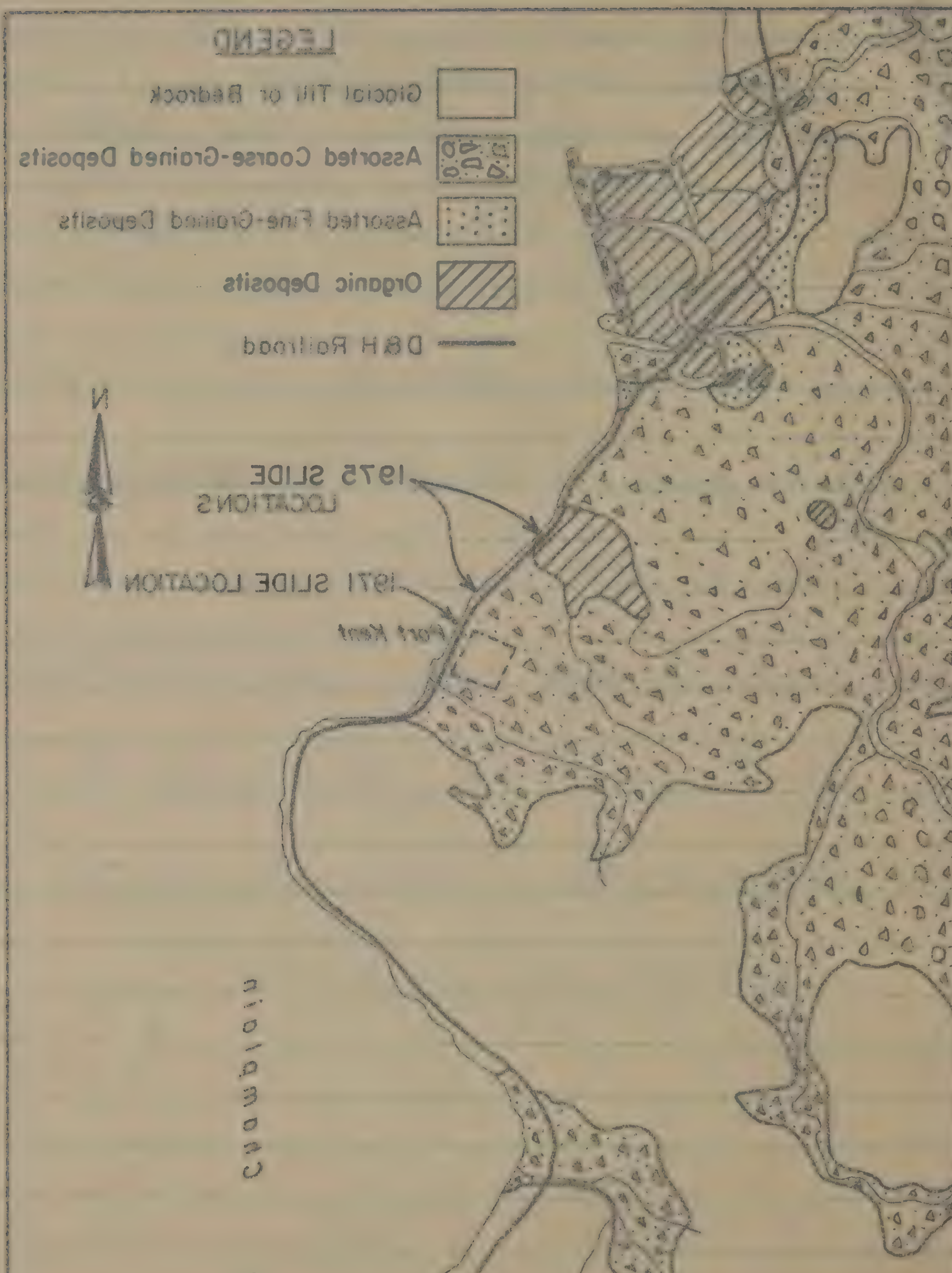
SUCESS of THE SURVEY WILL BE DETERMINED

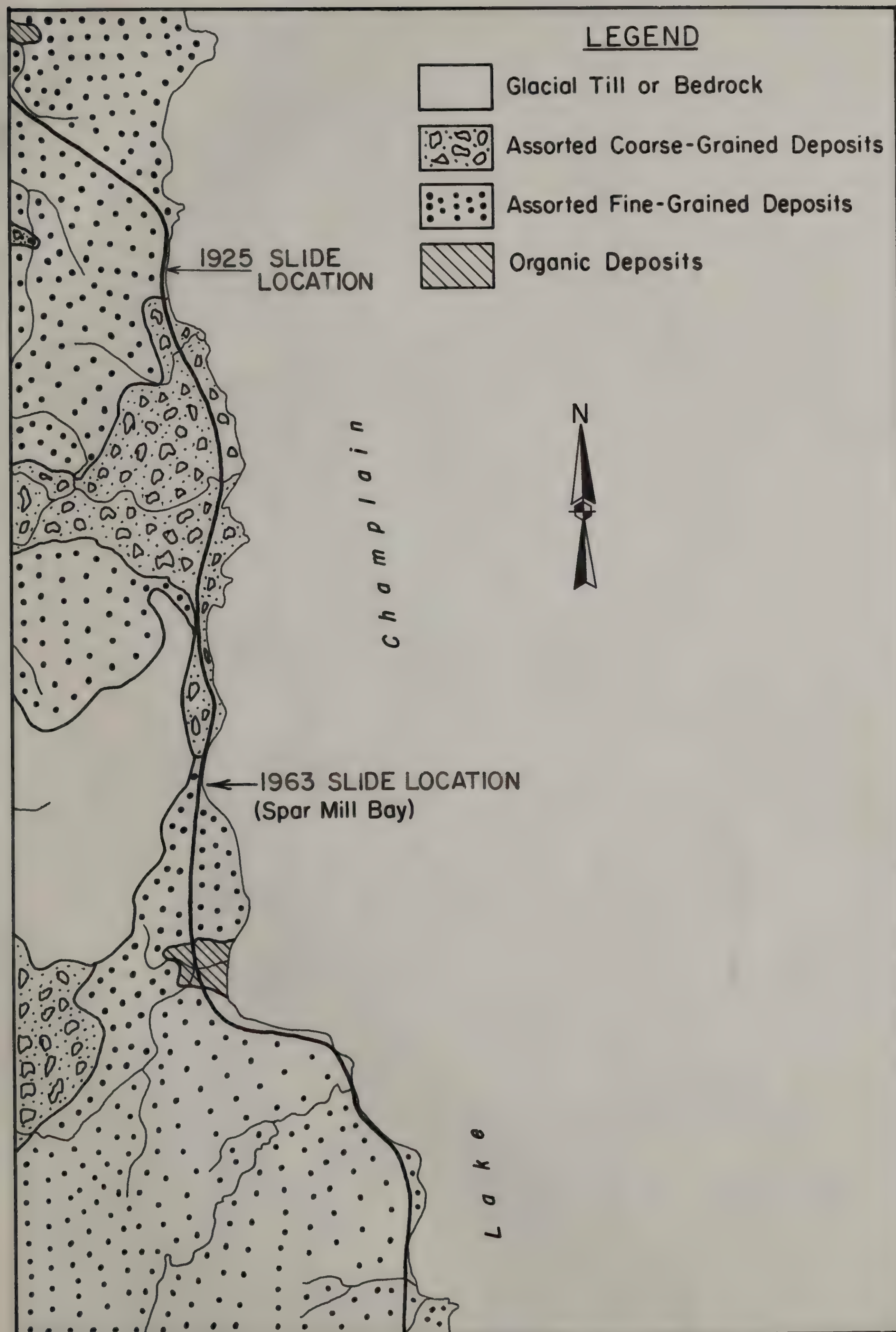
by A comparison of The cost of The

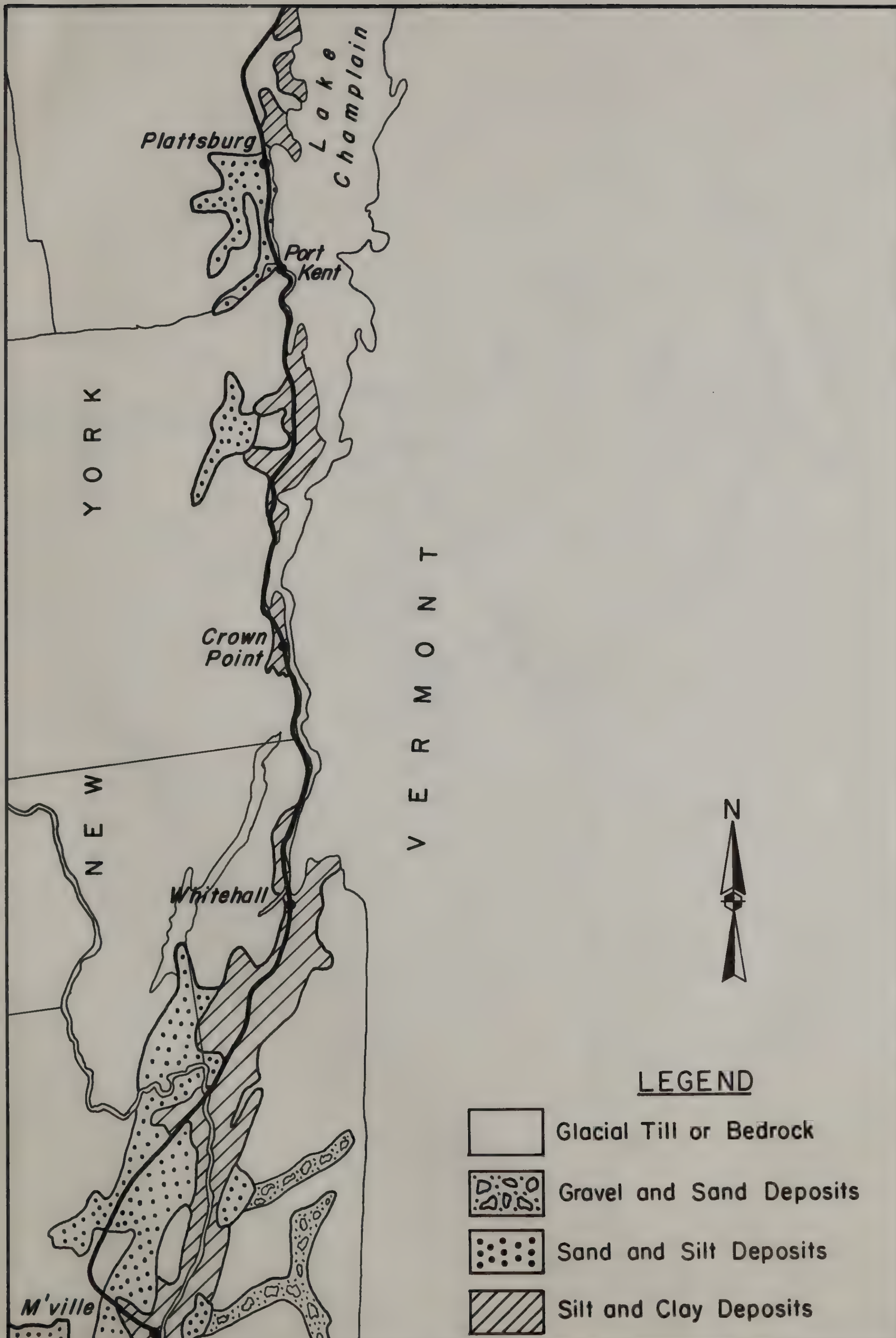
Proposed PERMENENT TREATMENT. And The yearly

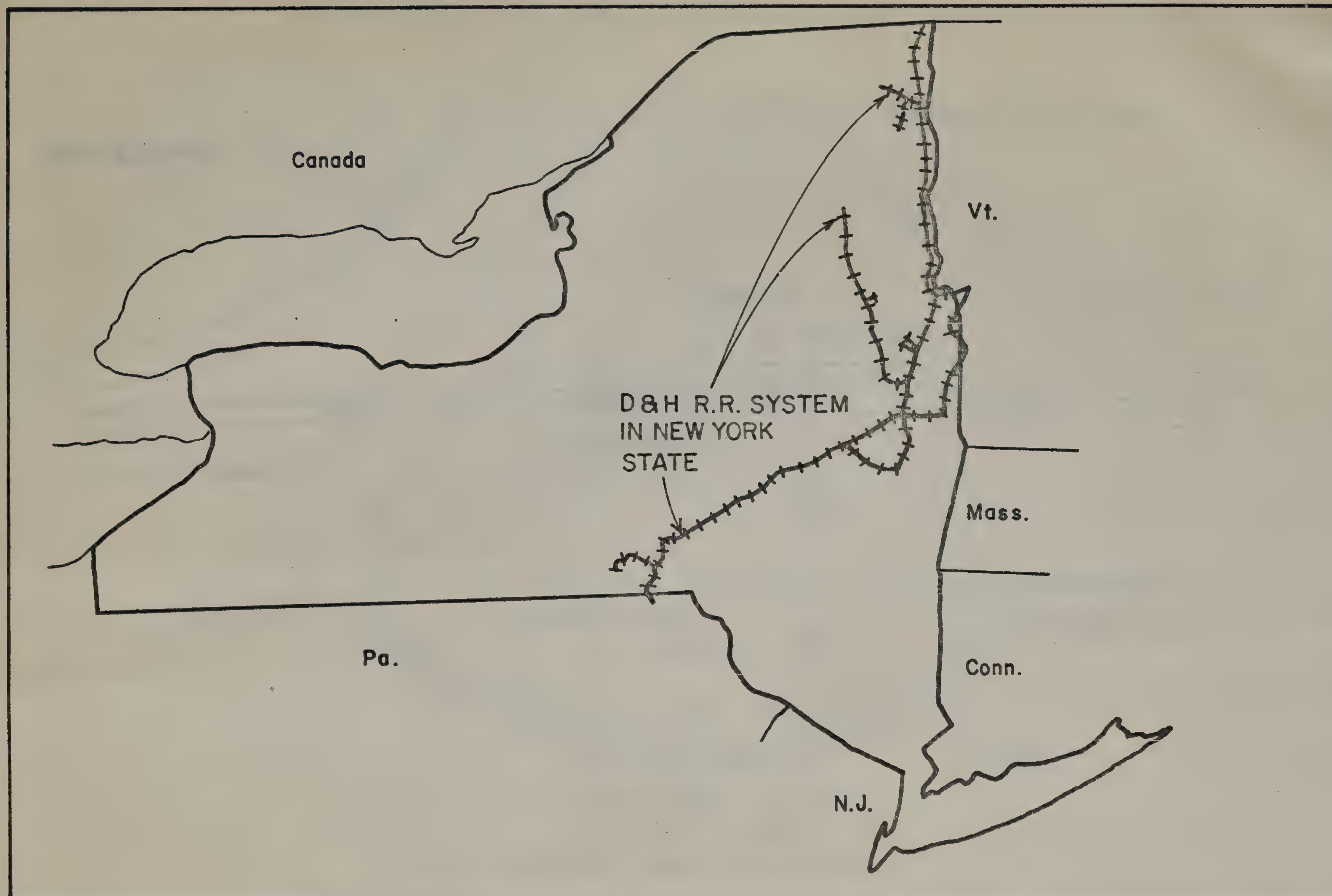
MAINTENANCE COSTS for THE RR.

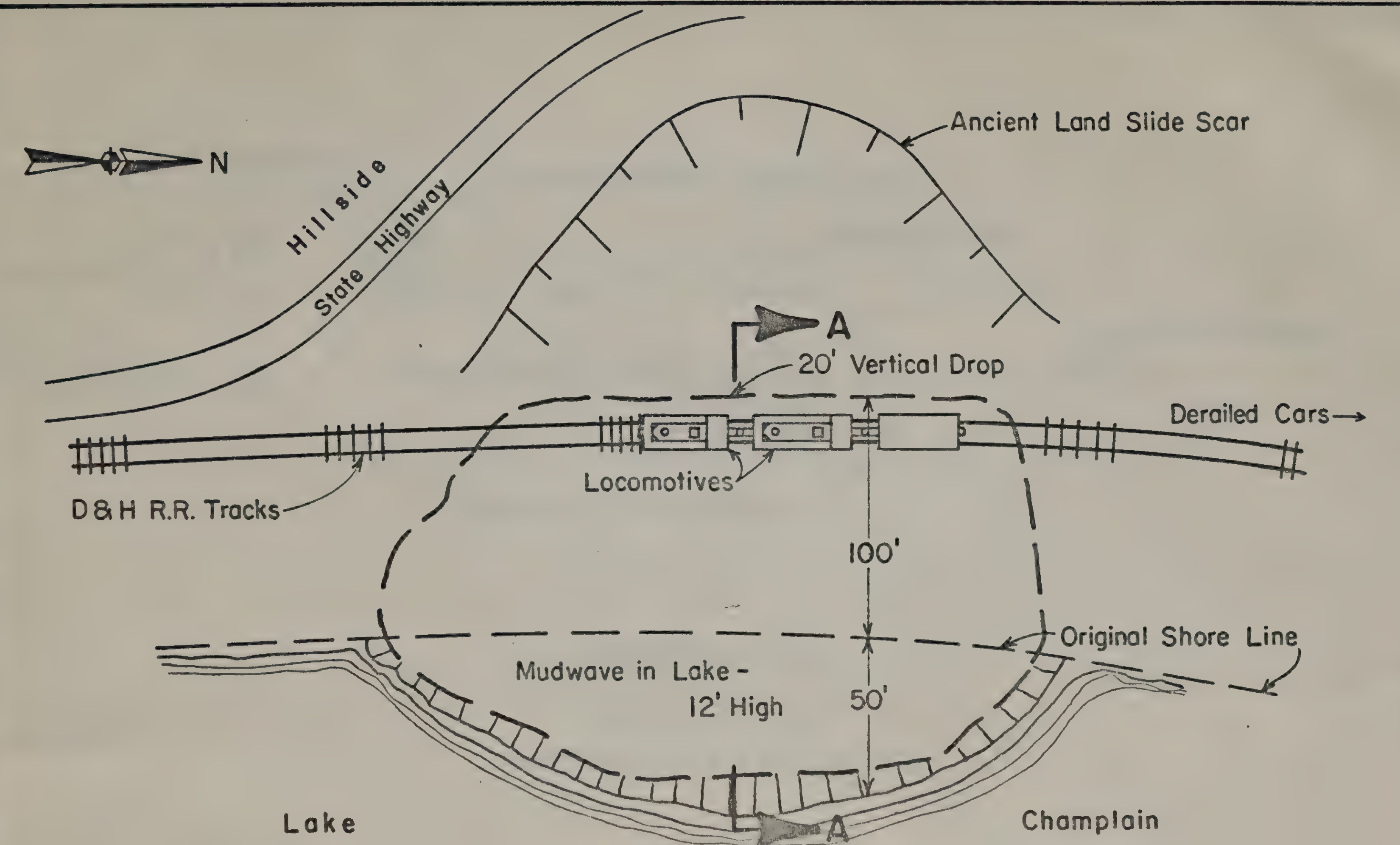

LEGEND
Glacial Till or Bedrock
Assorted Coarse-Grained Deposits
Assorted Fine-Grained Deposits
Organic Deposits
D&H Railroad
N
1975 SLIDE LOCATIONS
1971 SLIDE LOCATION
Port Kent
Lake Champlain


LEGEND
Glacial Till or Bedrock
Assorted Coarse-Grained Deposits
Assorted Fine-Grained Deposits
Organic Deposits
D&H Railroad
N
1975 SLIDE LOCATIONS
1971 SLIDE LOCATION
Port Kent
Lake Champlain

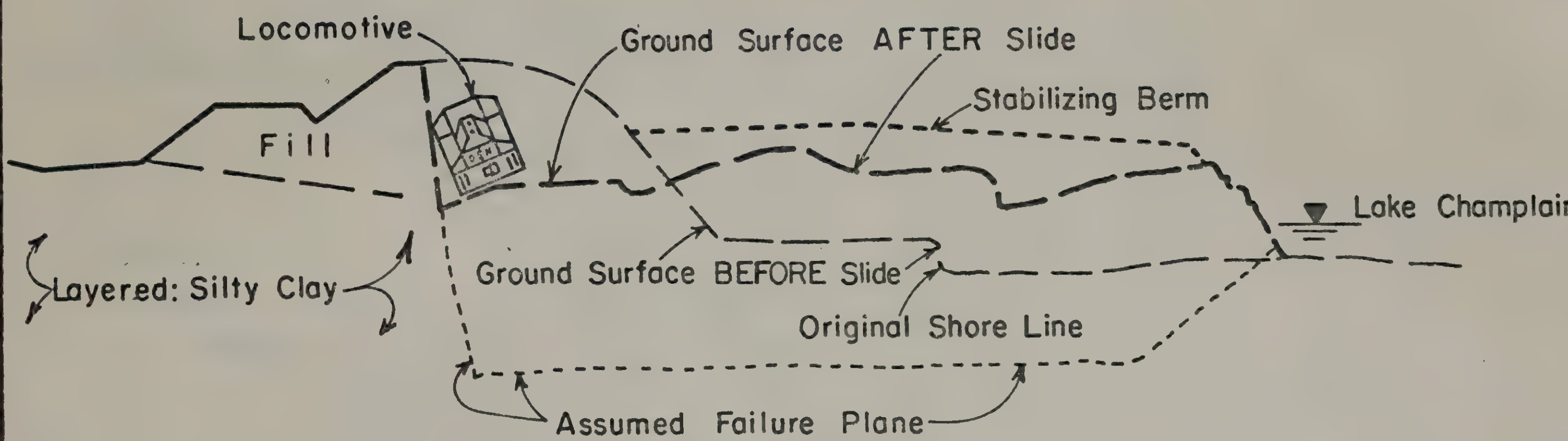

LEGEND
Glacial Till or Bedrock
Assorted Coarse-Grained Deposits
Assorted Fine-Grained Deposits
Organic Deposits
1925 SLIDE LOCATION
1963 SLIDE LOCATION
(Spar Mill Bay)
N
Champlain
Lake


Lake Champlain
Plattsburg
Port Kent
NEW YORK
Crown Point
VERMONT
Whitehall
M'ville
N
LEGEND
Glacial Till or Bedrock
Gravel and Sand Deposits
Sand and Silt Deposits
Silt and Clay Deposits


Canada
Vt.
D&H R.R. SYSTEM
IN NEW YORK
STATE
Mass.
Conn.
Pa.
N.J.



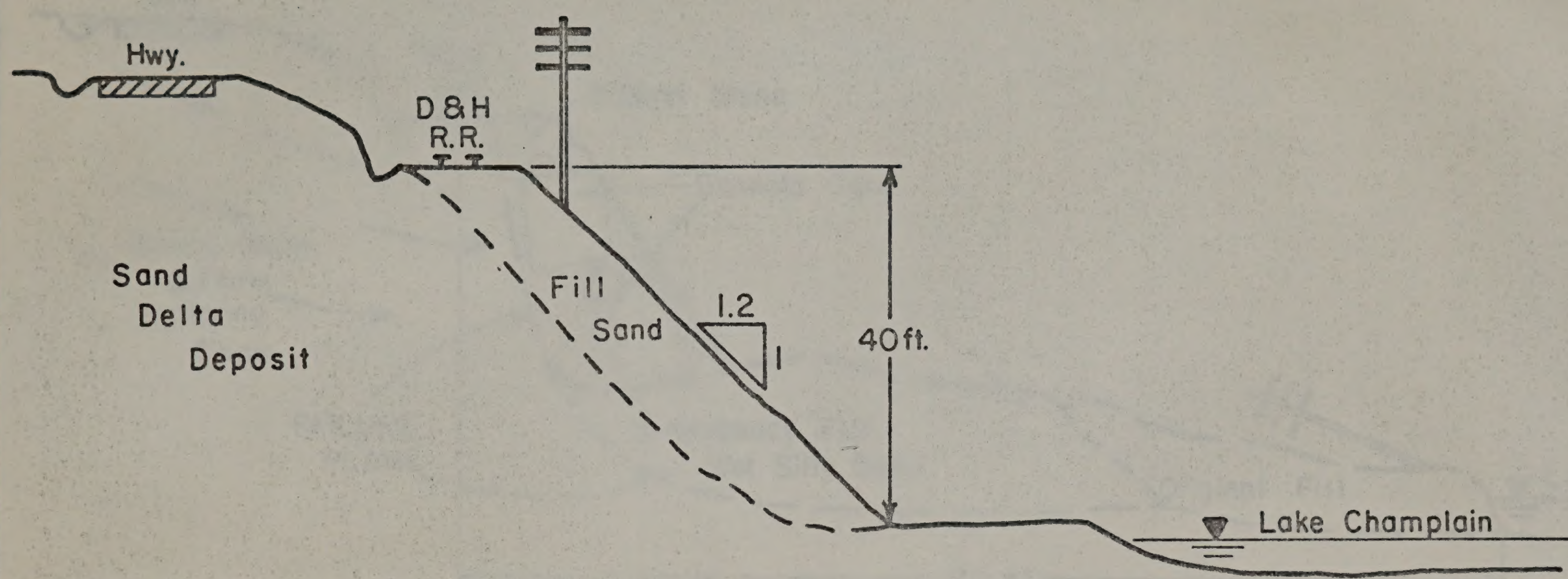
LOCATION PLAN
D&H R.R. SLIDE
SPAR MILL BAY, N.Y. - June 1963



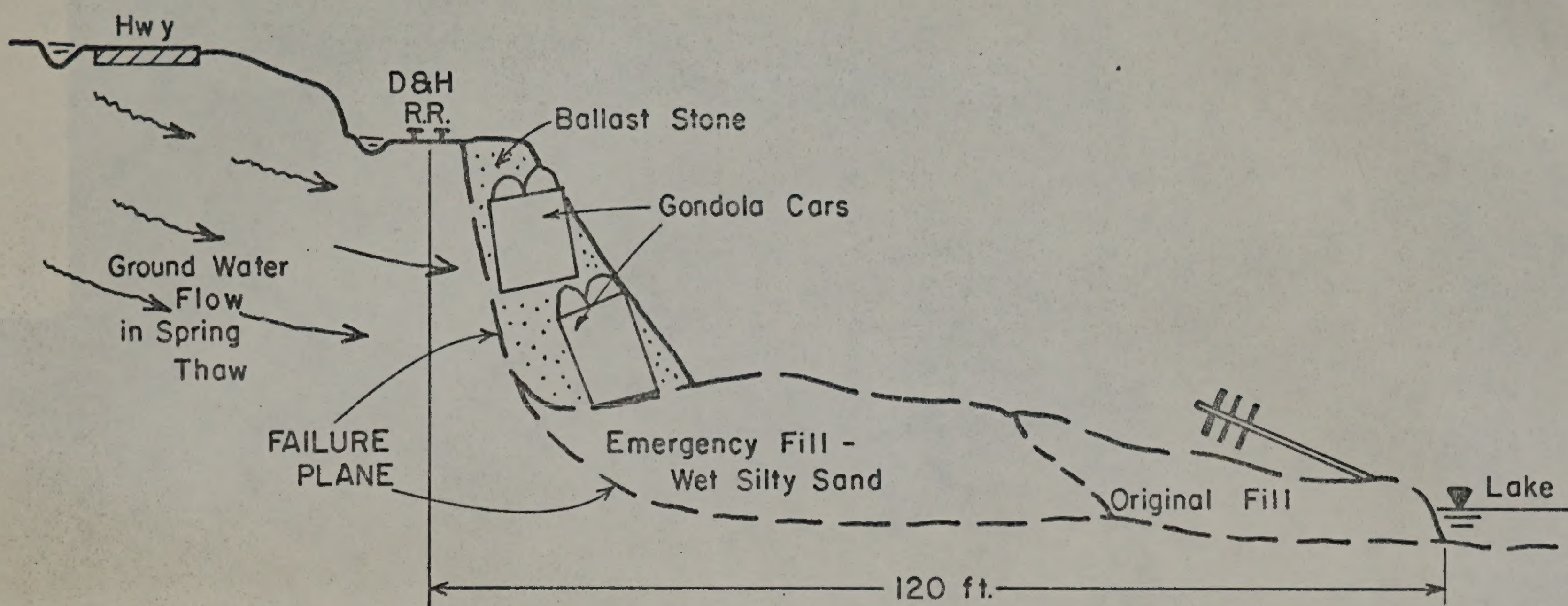
SECTION A-A

D&H R.R. SLIDE

SPAR MILL BAY, N.Y. - June 1963



CONDITIONS BEFORE FAILURE
D&H R.R. SLIDE
PORT KENT, N.Y.-April 1971



FAILURE AND REPAIR SEQUENCE
D&H R.R. SLIDE
PORT KENT, N.Y. - April 1971